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PART I

GENERAL (

INTRO

of the natural scien
ses of nature. The
which is devoted to a
and the general sci
of nature. The g
mistry.

other division of t
history, botany,
ing natural philo
accordance with
and also take
al substances,
water, etc.
It is also th

Physics is the science of the alteration of the state of a bo
ndation is the law of the conservation of force (e.g. energy
of force (e.g. energy) occurs in any physical process, b
transformation of one form of energy into another form
nomena in which the matter undergoes no alteration in
on belong to the domain of physics.

'or example, a rod of glass or a piece of sulphur after being
h a cloth attracts light bodies, a steel rod after rubbing with a
racts objects of iron, and ice is transformed by warming into wa
n into steam, but neither the glass, the sulphur, the steel,
ter undergoes any change in composition.
'he law of the conservation of energy constitutes the first prin
mechanical theory of heat. The second principle of this
lies particularly to the transformation of heat into mechanical
nly when heat passes from a warmer to a cooler body can it b
med into mechanical work, and indeed this is true for only a
tion of the heat which passes. That portion of the heat energ
be converted into work is called the available energy."

Divisions of Chemistry.

distinction is made between pure chemistry, which is
h chemistry solely for its own sake, and applied chemistry
isiders chemistry in relation to certain special interest
ording to the purpose which it serves it is denoted as
rmaceutical, technical, agricultural, physiological, etc., ch
nalysis and Synthesis.—Analytical chemistry or analysi
the development of pure and applied chemistry and is e
the purpose of resolving the more complex substances into

urea (a product of animal life) by Wöhler in 1828, the
eached that similar laws applied to the products of living
ature, and that the assumption of a special vital force
oundation. Since then a great number of organic prod
nd animal origin have been artificially prepared and also a
f compounds closely related to these, so that now a class
rganic and inorganic chemistry according to the older
e quite impossible.

Many solid organic substances, e.g., wood, muscle, lea
rganized, i.e., they have a characteristic structure, the s
f which is the cell. The cell is the result of the vital pro
ot be artificially produced, while it will ultimately be possib
he chemical constituents, in common with all other organi

I. STOICHIOMETRY.

Simple and Compound Substances.

All existing substances can be divided into compound and simple substances.

1. *Complex substances* or *compounds* can be separated into two or more substances differing from one another and from the original substance, namely, into two or more elements.

2. *Simple substances* or *elements* are those substances which, up to the present, have resisted all efforts to resolve them into more simple constituents. When elements enter into chemical combination their properties disappear entirely or partly and compounds with new properties appear, the actual substance of the elements themselves remaining unaltered, which is shown by the fact that the elements can be again separated by chemical means, and numerical quantities of the compound result as the sum of the numerical quantities of the elements which have formed them (additive property, p. 30). In spite of the enormous number of compounds occurring on the earth, the number of the elements from which they are built up is not great and the compounds essential to mankind are formed from only about one-half of the known elements. At present 78 elements (table, p. 25) are known, and in addition to these 8–10 substances are designated as elements which in all probability are mixtures of unknown elements whose separation will be possible by he use of improved methods.

That this small number of elements can form all known compounds ill be understood by a consideration of the law of multiple proportions p. 11). Only about a third of the elements occur free in nature.

Certain elements are universally distributed; for example, oxygen contained in the air, in water, and in the solid crust of the earth in uch quantity that it constitutes nearly one-half of the weight of the lobe, while other elements, like cerium, lanthanum, etc., appear only certain places and in very small quantities. The elements are very nequally distributed on the earth; up to the present 7 have been found the air and 30 in the water of the ocean, while all are more or less

Aluminium, 8.2 Calcium, 3.7
, 27.9 Iron, 4.8 Magnesium, 2.8 Potass

shown by spectrum analysis (p. 46), the elements of w
is formed constitute also the other heavenly bodies.
on, however, in addition to the positively known elemen
hers of whose existence we are at present entirely ignora
cording to geological hypothesis the centre of the earth is
lten substances, small quantities of which escape to the
volcanic eruptions. Since the radius of the earth is 40
the solid crust is only about 25 miles in thickness, it is possi
nts exist in the interior which, owing to their high specific
not yet reached the surface; this appears the more probal
ecific gravity of the globe itself is 5.6, while that of the
.5. Moreover, the periodic system of the elements (p. 54
the existence of about 18 elements as yet undiscovered.

Chemical Processes.

e processes involving a change in substance are called c
sses or transformations, or, in general, chemical reaction

the restricted sense the name chemical reaction is applied
cal processes which serve for the identification of given sub
he substances employed for the purpose of such tests ar
ts.

ery element and every compound can take part in a c
n, but the ability to do this varies within wide limits.
compounds offer extreme resistance to an alteration
sition, other compounds are stable only under very
ions. The following classification of chemical reac
upon the final products:

If two or more different elements or substances unite
e new substance, this is called a *union* or a *combinati*

ich promote the decomposition are removed, ts recombine to form the original substance, led *dissociation.*

s mutually exchange certain of their con- is known as *multiple decomposition* (double, ion), e.g., $AB+CD=AC+BD$.

esses known as *condensation, polymerization,* *transformation* will be discussed later.

hemical processes can take place simultaneously, he entire process becomes very complicated, and npound is almost always dependent on a previous reacting substances, and a decomposition with a of the decomposition products.

s which lead to the formation of compounds more riginal substances are called *synthetic* processes, and simpler compounds are called *analytical* processes.

Causes of Chemical Change.

se of the combination of reacting substances is a ffinity, by which is understood a force of attraction he separate elements, tending to bring them together n combined in the resulting compound. The affinity s elements is of different magnitude, and indeed with me element varies greatly under different conditions.

ffinity is not identical with chemical energy, since the the force which causes the chemical work, while the latter rk which is performed in chemical reactions by or against the y (and other forces which are also involved). The relation of ity to chemical energy is similar to that of the weight of a work which the body could perform through the medium ; this work depending both on the weight of the body and t through which it falls.

ce of affinity differs from other forces, as, for example, f gravitation and magnetism, in that it does not act at a for which reason substances which are to combine must t into intimate contact, and accordingly gases and liquids h one another more readily than solids, and the latter act nother more readily when powdered or amorphous than npact or crystalline.

sually necessary to start or to continuously support chemical y heat, electricity, light, or mechanical agitation.

Frequently a number of these forces act at the same time, heat being almost always present. The action of these forces, which are indeed only modes of motion, consists in imparting motion to the chemical substance (to the atoms, see p. 13), which not only excites this to enter into combination, but under some circumstances can be so violent as to cause through the motion a decomposition of the compound which is formed at first.

Affinity can, however, be accelerated or modified by certain other causes, namely, through the relative proportions of the reacting substances in solution, by the degree of electrolytic dissociation, by the solubility and volatility of the products formed, and also by the circumstance as to whether the substances are already extant or whether they enter into reaction at the moment of their production. Affinity is also modified by the presence of so-called catalytic agents, certain substances which, without undergoing any change themselves, influence the course of chemical reactions.

The chief causes which operate to promote the decomposition of complex substances into simpler ones, namely, those which tend to reduce or counteract the force of affinity, are likewise heat, electricity, light, and mechanical shock, since these forces can so increase the motion of the particles of chemical substances that the compounds break to pieces.

1. *Heat.* In general an increase of temperature up to a certain limit increases the combining power (affinity) of substances; on the other hand heating beyond a certain degree causes the decomposition of compound substances. For example, if mercury is heated in the air, it extracts oxygen from it and is converted into the red oxide of mercury; if the latter is heated to glowing, however, it decomposes again into mercury and oxygen (see further under Thermochemistry).

2. *Light* can cause both combination and decomposition (see further under Photochemistry).

3. *Electricity.* The action of the electric spark, through the increase in temperature which accompanies it, can cause either combination or decomposition. The electric current produces apparent decomposition; in reality its effect is to separate from one another the products of decomposition already set free by other forces (see further under Electrochemistry).

4. *Mechanical shock* can promote the combination of many substances, but it can also produce decomposition by destroying the structure of many compounds, often with an explosion. In many cases, however, the cause of the chemical change is due directly to the heat produced by the mechanical shock, or to the more intimate contact due to the jar and pressure.

5. *Electrolytic Dissociation* (see under Theory of the Ions).

6. The relative quantities of the reacting substances present often exert a pronounced influence on the course of the reaction. For example,

ine sets bromine free from potassium bromide and forms potassium ride, while a proportionately large quantity of bromine sets chlorine from potassium chloride and forms potassium bromide. A solution taining a small quantity of an active substance usually acts more ly than one containing a large quantity of the active substance, ile in many cases the weaker solution has no perceptible action whater. For example, copper is dissolved only by concentrated sulphuric id (see further under Chemical Mechanics).

7. *The influence of the solubility and volatility* of the resulting subances is always very strong and characteristic. When brought together solution only those substances combine which can form insoluble or ifficultly soluble compounds. If, for example, acetic acid is added to n aqueous solution of potassium carbonate, there is formed potassium cetate, and carbon dioxide is set free; but if carbon dioxide is passed into n alcoholic solution of potassium acetate, potassium carbonate and ree acetic acid are formed, since potassium carbonate is insoluble in lcohol.

Non-volatile or slightly volatile substances at higher temperatures displace more volatile substances having stronger ability to react. For example, when silicic acid is fused with a salt of sulphuric acid, the weaker silicic acid displaces the stronger sulphuric acid, since the former is not volatile, while in aqueous solutions salts of silicic acid are decomposed by sulphuric acid, silicic acid being set free.

8. *Catalytic Agents.* The presence of small quantities of certain substances promotes or retards the course of certain chemical reactions without any apparent change taking place in the substances themselves. Such substances are known respectively as positive or negative catalytic agents or contact substances, and their action is known as catalysis or catalytic action. For example, phosphorus or carbon do not burn when heated in absolutely dry oxygen, and many metals when placed in contact with it enter into no combination, but these substances combine as soon as even a trace of water is present. Cane-sugar is split into two kinds of sugar by the action of dilute acids, the acids themselves undergoing no alteration. The probable action of many positive catalytic agents is that they first combine with one substance and then give this up to the other; i.e., the action depends upon the formation of unstable intermediate products (see further under Hydrogen and Chloride of Lime). The action of most positive catalytic agents can be compared to the action of fresh oil on a clock which previously ran with much friction and very slowly because of old viscous oil on the pinions.

9. *The Nascent State* (status nascens). Substances show an increased affinity at the moment that they are set free from their compounds; for example, oxygen does not bleach vegetable colors, but when set free from water by chlorine does so instantly (see p. 17).

Weight and Volume Relations in Chemical Reactions.

The combination of elements follows certain laws which are called oichiometrical laws. The study of the laws governing the com nation of the elements and their application to chemical calcula ns is called stoichiometry in the restricted sense (p. 3).

1. Law of the Conservation of Matter.

The total weight of matter resulting from a combination or decomposition is always equal to the sum of the weights of all the substances taking part in the reaction.

Superficial observation appears to contradict this law, since, for example, when a candle is burned, matter seems to disappear. However, more careful investigation shows that when a candle burns, gaseous products are formed which are not directly perceptible (carbon dioxide and water vapor), and that the weight of these products corresponds exactly with the weight of the candle burned plus the weight of the oxygen of the air consumed in the combustion.

2. The Law of Constant Proportions.

The elements do not combine with one another to form compounds in indefinite, but in absolutely fixed and unalterable, relative proportions by weight.

Every definite compound therefore contains the elements of which it is composed in absolutely fixed, unalterable proportions by weight; for example, water, irrespective of its source, always consists of 8 parts of oxygen and 1.01 parts of hydrogen, common salt always of 23 parts of sodium and 35.4 parts of chlorine.

If the proportions by weight in which one element combines with others is known, then the proportions by weight in which the other elements combine with one another is known also. *The constancy of the proportions by weight sharply distinguish chemical compounds from mixtures.*

The constant combining proportions have been investigated for all compounds; the values obtained from analysis or synthesis were first calculated on the basis of 100 parts of the compound, but the attempt was soon made to find a simpler expression for these relations and to bring them into conformity with the combining relations of all other elements.

This can be accomplished, for example, when oxygen, which combines with almost all other elements, is taken as the point of departure. In order to allow a comparison with the combining weights now in use, namely, the atomic weights, the figures given below are calculated on the basis of how much of the different elements combines with 8 parts of oxygen, rather than with 1 part of oxygen.

Thus 8 parts of oxygen combine with 1.01 parts of hydrogen to form water, with 35.4 parts of chlorine to form chlorine monoxide, with 16 parts of sulphur, with 4.68 parts of nitrogen to form nitrous anhydride, with 3 parts of carbon to form carbon dioxide, with 27.5 parts of manganese to form manganous oxide, with 23 parts of sodium to form sodium oxide, with 31.8 parts of copper to form cupric oxide, with 100 parts of mercury to form mercuric oxide, and with 28 parts of iron to form ferrous oxide.

Consequently 1.01 parts of hydrogen will combine with 35.4 parts

chlorine, 16 parts of sulphur, 4.68 parts of nitrogen, an
bon, and further 35.4 parts of chlorine or 16 parts of
nbine with 27.5 parts of manganese, 23 parts of sodium,
copper, and 100 parts of mercury, etc.

The proportions by weight in which the elements e
bination are called *combining weights* and since they
e chemical values as the proportions by weight in whi
ace or displace one another in chemical decompositions,
also called *equivalent weights* (p. 12).

or example, if a rod of copper is placed in a solution of mer
ide (a compound of 100 parts of mercury with 35.4 parts of chlori
r passes into solution until all of the mercury has separated ou
very 100 parts of mercury which separate it will always be foun
1.8 parts of copper enter into combination with 35.4 parts of chlorine.

3. Law of Multiple Proportions.

ny elements can combine with one another in more than one
tion by weight, that is, they can form more than one compound, a
stance which appears to contradict the law of constant propor-
If, however, these proportions by weight are examined more
it is found that they are always a whole multiple of the lowest
by weight of the given element which enters into combination.

example, nitrogen forms five compounds with oxygen:

.68) pts. N. with 8 pts. O. gives nitrous oxide.
.68) " " " 16 (2×8) " " " nitric oxide.
.68) " " " 24 (3×8) " " " nitrous anhydride.
68) " " " 32 (4×8) " " " nitrogen dioxide.
68) " " " 40 (5×8) " " " nitric anhydride.

nese and oxygen also form five compounds:

Mn. with 8 pts. O. form manganous oxide.
" " 16 (2×8) " " " manganese peroxide.
" " 24 (3×8) " " " manganic oxide.
" 32 (4×8) " " " manganous-manganic oxide.
" 56 (7×8) " " " permanganic anhydride.

*2×27.5. †3×27.5. ‡2×27.5.

mical process, the relative weights of the reacting elements
t correspond to the laws of constant or multiple propor-
excess of the particular element remains uncombined.
if 100 parts of copper are heated with 100 parts of sulph
of copper combine with 16 parts of sulphur, then 100
copper with 50.3 parts of sulphur, and
vill remain uncombined, since 31.8
ulphur ($x=50.3$).

The ability of the elements to combine with one another in several proportions by weight, as well as the tendency to combination of the smallest parts (the atoms, p. 13) of the elements, explains the enormous number of compounds.

4. Law of Simple Proportions by Volume.

The combination of elements or compounds existing in the form of gases takes place according to certain simple relations by volume: *The measured volume of a gaseous compound produced by the combination of two or more gaseous substances is equal either to the sum of the volumes of its components or else is smaller than this in a ratio expressible by whole numbers* (Gay-Lussac's law of volumes). If the volume of that gas which enters into the reaction in the proportion of one volume be taken as unity, then the volume of gas resulting from the combination of elementary gases will occupy the space of two volumes, irrespective of the variation of the sum of the volumes of the reacting gases.

1 vol. (1.01 parts) of hydrogen + 1 vol. (35.4 parts) of chlorine give 2 vols. (36.41 parts) of hydrogen chloride.

2 vols. (2.02 parts) of hydrogen + 1 vol. (16.0 parts) of oxygen give 2 vols. (18.02 parts) of water vapor.

3 vols. (3.03 parts) of hydrogen + 1 vol. (14.04 parts) of nitrogen give 2 vols. (17.07 parts) of ammonia gas.

4 vols. (4.04 parts) of hydrogen + 1 vol. (12.0 parts) of carbon give 2 vols. (16.04 parts) of marsh-gas.

Since the gases, like all other substances, can combine only in definite proportions by weight, therefore the weights of the volumes of the combining gases must stand to one another in the same ratio as the combining weights of the elements which constitute the gases.

The combining or equivalent weights calculated on the basis of oxygen =8, which were given above as examples, were formerly used as the foundation of all chemical calculations, but have been abandoned, since under certain circumstances different combining weights were obtained for one and the same element so that the choice became optional and uncertainty resulted. For example, manganous oxide consists of 27.5 parts of manganese and 8 parts of oxygen, manganic oxide of 18.33 parts of manganese and 8 parts of oxygen (p. 11); further, nitrous anhydride of 4.68 parts of nitrogen and 8 parts of oxygen, nitrogen dioxide of 3.51 parts of nitrogen and 8 parts of oxygen (p. 11); further, methane of 3 parts of carbon and 1.01 parts of hydrogen, ethane of 4 parts of carbon and 1.01 parts of hydrogen. This variation in composition is explained by the law of multiple proportions (since 27.5 manganese=3×9.17 and 18.33 manganese=2×9.17; 4.68 nitrogen=4×1.17 and 3.51 nitrogen y, for every increase in temperature of 1° C. the volume of expands $\frac{1}{273}$ of its volume at 0° C.

equently the pressure that a gas on warming at constant volum n the surrounding walls for every 1° increase in temperature must $\frac{1}{273}$ of its pressure at 0° centigrade.

laws are explainable by

vogadro's hypothesis: *Equal volumes of all gases at the essure and temperature contain an equal number of molecules.* re by a comparison of the weights of equal volumes of differ-s at the same pressure and temperature the relative weights nolecules can be determined.

rning the apparent deviation of many gases from Avogadro's sis see "Thermochemistry and Dissociation."

he smallest particles of the free elements consist generally, like pounds, of molecules and not of free atoms.

vogadro's hypothesis this can be demonstrated as follows:

$$\underset{\text{1 vol.}}{\boxed{\begin{matrix}100\\ H_2\end{matrix}}} + \underset{\text{1 vol.}}{\boxed{\begin{matrix}100\\ Cl_2\end{matrix}}} = \underset{\text{2 volumes.}}{\boxed{\begin{matrix}100\\ HCl\end{matrix} \Big| \begin{matrix}100\\ HCl\end{matrix}}}$$

$$\underset{\text{2 vols.}}{\boxed{\begin{matrix}100\\ H_2\end{matrix} \Big| \begin{matrix}100\\ H_2\end{matrix}}} + \underset{\text{1 vol.}}{\boxed{\begin{matrix}100\\ O_2\end{matrix}}} = \underset{\text{2 volumes.}}{\boxed{\begin{matrix}100\\ H_2O\end{matrix} \Big| \begin{matrix}100\\ H_2O\end{matrix}}}$$

$$\underset{\text{3 vols.}}{\boxed{\begin{matrix}100\\ H_2\end{matrix} \Big| \begin{matrix}100\\ H_2\end{matrix} \Big| \begin{matrix}100\\ H_2\end{matrix}}} + \underset{\text{1 vol.}}{\boxed{\begin{matrix}100\\ N_2\end{matrix}}} = \underset{\text{2 volumes.}}{\boxed{\begin{matrix}100\\ NH_3\end{matrix} \Big| \begin{matrix}100\\ NH_3\end{matrix}}}$$

certain volume of hydrogen contains 100 molecules of hydro-n an equal volume of chlorine contains the same number of molecules. By the combination of this 1 volume of hydrogen 1 volume of chlorine, 2 volumes of hydrogen chloride (p. 12) ained, which consequently must contain 200 molecules of n chloride. But 200 molecules of hydrogen chloride must 200 atoms of hydrogen and 200 atoms of chlorine; therefore in nation of hydrogen chloride each molecule of hydrogen and has split into 2 parts, that is to say, each of the molecules of n and chlorine consists of 2 atoms. Similarly 1 volume of with hydrogen furnishes 2 volumes of water vapor, 1 volume gen with hydrogen 2 volumes of ammonia-gas, so that here nitrogen has separated into two

rt the theory that the molecules of
of atoms (exceptions, p. 21), such
cations of the elements (see Ozone),
eactions (see Hydrogen Peroxide),
e elements at the moment that they
ls (p. 9), which can be explained in
state the atoms have already com-
finity is already partly satisfied; there-
ment can enter into a compound, the
hich it is held in the molecule by the
noment that an element is released
oms are quite free and can then act
ffinity much more energetically upon

ations it is evident that
lest relative quantity by weight of an
pears in the free condition.
lest relative quantity by weight of an
the molecular weights of any of its com-

nent holds good only so long as no com-
ains in the molecule a still smaller quan-
previously found.

elative weights of atoms and molecules it
y to select one substance as a starting-
unit, and to compare all other substances
and molecular weights with this one sub-
d.

chosen is 1 volume of oxygen = 1 atom of
of oxygen.

simplest plan to refer all the quantities by pressure (are isotonic: ἴσος, *equal*, τόνος, *tension*), the same depression of the freezing-point, the same lowering of the vapor pressure, and correspondingly the same elevation of the boiling-point. The molecular weight of a substance which dissolves without decomposition is therefore determined by dissolving a small, accurately weighed quantity of the substance in a known quantity of a liquid, and determining the osmotic pressure or the vapor pressure or, what is simpler, the freezing- or boiling-point. The value thus obtained is compared with that which is obtained when a substance of known molecular weight in a corresponding gram-quantity is dissolved in the same quantity of the same liquid.

For example, a quantity of a substance of known molecular weight, corresponding to its molecular weight when dissolved in 1000 grams of benzene (if soluble therein), will lower the freezing-point of the solvent by 4.9°. Therefore if the addition of a known quantity x of a substance of unknown molecular weight to 1000 grams of benzene lowers the freezing-point 9.8°, the molecular weight of the unknown substance must be equal to one-half of x, since $9.8=2\times4.9$.

If the osmotic pressure, etc., are determined in aqueous solutions, the solutions of acids, bases, and salts show greater osmotic pressures, etc., than would be expected from the theory, and therefore for the determination of the molecular weight of these substances other solvents than water (e.g., acetic acid, benzene, pyridine, etc.) must be employed. Concerning the cause of these exceptions see Theory of the Ions.

Properties, like the osmotic pressure, the expansion and pressure of gases, which can assume similar values for chemically comparable quantities of unlike substances, are called colligative properties (*colligare*, to bind); these, in contradistinction to the additive properties (p. 30), are influenced only by the number of the molecules, not by their nature or constitution.

3. Molecular Weight of Substances which are Volatilized with Difficulty.

The molecular weights of the metals which come under this class are determined similarly to the molecular weights of dissolved substances. If small equimolecular quantities of other metals are melted together with larger and equal quantities of certain metals (bismuth, lead, cadmium, tin), the resulting products (alloys) correspond to dilute solutions and show a corresponding equal lowering of the melting-point. Therefore by determining the melting-point of an alloy prepared from a metal of unknown molecular magnitude, its molecular weight can be calculated in the manner described in 2.

NATION OF THE ATOMIC WEIGHT.

termination from the Molecular Weight.

nic weight is the smallest quantity of an element n the molecular weight of any of its compounds, it y to determine, by the analysis of all compounds of ent, in which of these compounds the smallest quantity the element is present in a quantity of the compound g to its molecular weight.

mple, the atomic weight of carbon was determined in this ne molecular weight of a compound of carbon with hydrogen, alled marsh-gas, is 16.04; in 16.04 parts of this gas there are 1 12 parts of carbon and 4.04 parts of hydrogen. The atomic f carbon could be equal to 12, 6, 3, etc., that is, in one molecule h-gas there could be 1, 2, 4, etc., atoms of carbon combined with toms of hydrogen, but since of all the compounds of carbon which been examined not a single one of these contains less than 12 parts rbon in the molecule, the number 12 must be taken as the minimum tomic weight of carbon.

From the assumption that a molecule of every substance in a seous condition occupies the same volume as 2 volumes = 2 atoms f oxygen, it might be concluded that 1 atom of any elementary gas occupies the same volume as 1 volume = 1 atom of oxygen, so that the gas densities of the elements would also be their atomic weights, and that by a comparison of the weights of equal volumes of the given gas and of oxygen the relative weights of the atoms could be determined. With certain elements, however, the weights thus found do not correspond to the atomic weights; for example, different atomic weights are found for sulphur and iodine at different temperatures (see Dissociation); moreover, the molecular weight of phosphorus as determined from its gas density is 124, that of arsenic 300, and accordingly their atomic weights must be 62 and 150 respectively. But the minimum weights which have been found by chemical analysis in any of their compounds (i.e., in molecular quantities of phosphine and arsine) correspond to only 31 for phosphorus and 75 for arsenic. When in a gaseous condition their molecules therefore consist of 4 atoms.

In the case of metals the minimum weight which is found in the molecular weights of the corresponding compounds is of the same ıry vapor and 2 volumes of chlorine give 2 volumes of mercuric vapor; if the 2 volumes of mercury vapor contain 200 molecules, e 2 volumes of resulting mercurous or mercuric chloride vapor kewise contain 200 molecules (p. 16, *d*), and therefore in the l combination of the mercury no splitting up of mercury molen have taken place.

compounds of all metals in a gaseous condition occupy the pace as the vapors of the metals which are contained in them, e the molecules of the vaporized metals are not further divisible, ıey enter into chemical combination the number of the molecules ısequently the space which they occupy cannot be increased.

2. Determination from the Specific Heat.

s method depends upon a relation which exists between the weight and the specific heat of every solid element, and also to check the atomic weights found by other methods.

cific heat is the number of heat units (see Thermochemistry) it is necessary to add to 1 gram or 1 kilogram of a substance in o raise its temperature by 1° C. In the case of solids this quantity t can be readily determined.

order to warm equal quantities of two substances to the same ature two different quantities of heat are necessary. Thus, for e, in order to warm a given quantity of water to a certain tem-re, a quantity of heat is required which is thirty-one times as great which would be required in order to produce the same increase perature in a quantity of platinum of equal weight. The specific platinum is therefore only $\frac{1}{31}$ of that of water, or expressed as l fraction 0.032. The specific heat of one and the same substance according to its state of aggregation.

the specific heat of the elements in the solid state is calculate basis of the atomic weight, instead of on the basis of equ ities, it is found that quantities of the elements taken in pr

ELEMENTS WITH ATOMIC WEIGHTS.

Name.	Symbol.	Atomic Weight.	Name.	Symbol.	Atomic Weight.
ium.	Al	27.1	Neon	Ne	20.0
ony (Stibium)	Sb	120.2	Nickel	Ni	53.7
	A	39.9	Niobium	Nb	94.0
	As	75.0	Nitrogen	N	14.04
	Ba	137.4	Osmium	Os	191.0
um.	Be	9.1	Oxygen	O	16.0
h	Bi	208.5	Palladium	Pd	106.5
	B	11.0	Phosphorus	P	31.0
ne	Br	79.96	Platinum	Pt	194.8
m.	Cd	112.4	Potassium (Kalium)	K	39.15
	Cs	132.9	Praseodymium	Pr	140.5
n.	Ca	40.1	Radium	Ra	225.0
	C	12.0	Rhodium	Rh	103.0
	Ce	140.25	Rubidium	Rb	85.4
e.	Cl	35.45	Ruthenium	Ru	101.7
ium.	Cr	52.1	Samarium	Sa	150.0
	Co	59.0	Scandium	Sc	44.1
(Cuprum)	Cu	63.6	Selenium	Se	79.2
	Er	166.0	Silicon	Si	28.4
ne.	F	19.0	Silver (Argentum)	Ag	107.93
nium.	Gd	156.0	Sodium (Natrium)	Na	23.05
n	Ga	70.0	Strontium	Sr	87.6
nium.	Ge	72.5	Sulphur	S	32.06
Aurum)	Au	197.2	Tantalum	Ta	183.0
	He	4.0	Tellurium	Te	127.6
gen.	H	1.01	Terbium	Tb	160.0
	In	114.0	Thallium	Tl	204.1
	I	126.85	Thorium	Th	232.5
	Ir	193.0	Thulium	Tu	171.0
errum)	Fe	55.9	Tin (Stannum)	Sn	119.0
on.	Kr	81.8	Titanium	Ti	48.1
num.	La	138.9	Tungsten	W	184.0
Plumbum)	Pb	206.9	Uranium	U	238.5
n.	Li	7.03	Vanadium	V	51.2
sium.	Mg	24.36	Xenon	X	128.0
nese	Mn	55.0	Ytterbium	Yb	173.0
y(Hvdrargyrum)	Hg	200.0	Yttrium	Y	89.0
denum.	Mo	96.0	Zinc	Zn	65.4
mium.	Nd	143.6	Zirconium	Zr	90.6

taken as a whole or to that portion enclosed in the brackets for example, $3H_2SO_4$ or $(H_2SO_4)_3$ denotes 3 molecules of sul- acid; $Fe_2(SO_4)_3$ is the formula for an iron salt of sulphuric acid ndicates that this substance consists of 2 atoms of iron and nic complexes SO_4.

e formulas used express the molecular magnitudes of the

weight and volume in which the elements are p
cules of the compounds.

formula of a substance is given, it is possible to calculate the
a liter of the substance in a gaseous condition, as well as its
ravity with respect to any other gas taken as unity (p. 42, *b*),
these quantities to further calculate its gram-volume and
r volume, if only the molecular weight (=32) and the weight
(=1.4291) of oxygen are known. It must, however, be borne
that all considerations involving the volumes of gases must
on the volume occupied by gases under a pressure of 760 mm.
emperature of 0°. Since all specific gravities of gases are now
to the molecular weight of oxygen=32 as unit (p. 43), their
gravities are therefore directly expressed by their molecular
The formula NH_3, for example, consequently expresses the fol-
concerning one molecule of ammonia:
hat it consists of nitrogen and hydrogen.
hat it consists of 1 atom=14.04 parts of nitrogen and 3 atoms
01 parts of hydrogen and therefore has the molecular weight

hat it consists of 1 volume of nitrogen and 3 volumes of hydrogen.
hat it has the specific gravity 17.07 with respect to oxygen taken
; further, that its specific gravity with respect to hydrogen=1 is
nd with respect to air=1 is 0.59 (see p. 44).
hat 1 liter of it weighs 0.76 gram, that its molecular volume is
ers, and that its gram-volume is 1.31 liters.

the basis of these calculations see pp. 43, 44.

ddition to the empirical formulas mentioned above, in which
e symbols of the elements constituting the molecules are
ed, there are also the so-called rational formulas which indi-
e grouping of the atoms in the molecules (p. 29).

3. Chemical Equations.

f an element does not combine with hydrogen, then
termined from the number of other atoms, equiv
of hydrogen, with which it can combine.

om of chlorine combines with 1 atom of hydrogen to
" " oxygen " " 2 atoms " " "
" " nitrogen " " 3 " " " "
" " carbon " " 4 " " " "

Accordingly the valence of chlorine = 1, of oxygen =
= 3, of carbon = 4; and chlorine is therefore said to
ovalent, oxygen bi- or divalent, nitrogen trivalent,
dri- or tetravalent. It is also often customary t
rine possesses one and oxygen two bonds or units
ause it used to be believed that chemical affinity (p.
ted with the valency.

The valence is denoted by Roman numerals or horiz
ed near the symbols (p. 29).

The valence is not, like the atomic weight, an inherent
element, but is dependent upon the properties of the el
t upon one another. Every element exhibits, however,
nce. For example,

$$\begin{array}{ccccccc}
\overset{II}{CO} & \overset{III}{PCl_3} & \overset{III}{P_2O_3} & \overset{II}{SCl_2} & — & \overset{I}{Cl_2O} & - \\
\overset{IV}{CO_2} & \overset{V}{PCl_5} & \overset{V}{P_2O_5} & \overset{IV}{SCl_4} & \overset{IV}{SO_2} & \overset{III}{Cl_2O_3} & - \\
 & & & & \overset{VI}{SO_3} & \overset{V}{Cl_2O_5} & \overset{V}{Cl}
\end{array}$$

the carbon compounds, since there are considerable nu
ch, although of similar qualitative and quantitative
e quite different properties. This is known as isomeris

For example, the empirical formula NC_2H_7 stands for
nds, so that from this it cannot be determined whic
nds is denoted, while the rational formulas mentione
istantly possible to distinguish between them. The stu
isformations, the different methods of preparation, and th
anic compounds all lead to the assumption of a definit
he atoms in the molecules (see Part III, Isomerism and
the Constitution).

The method of writing these formulas suggests the a
atoms in a single plane; but since in reality the sepa
st have definite volume, the separate atoms must be
ributed through all three dimensions of space (concernin
it of the atoms in space see Part III, Stereochemistry

The unvarying arrangement of the atoms in the molecu
heir linking does not necessitate that the atoms are fixe
i respect to one another in the molecule, but it can be
withstanding this they move about a point of equilibrium

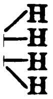
The constitution of salts containing water of crysta
ther similar double salts (see Magnesium Sulphate
ained by the assumption of an additional valency
atoms, for which reason it is supposed that in these
ral molecules are present and that these exert a
traction on one another. Such compounds are the
cular compounds. Example, $MgSO_4,K_2SO_4 . 6H_2O$.

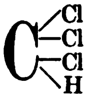
roperties of substances which depend upon the
ber of the atoms in the molecule are called *additiv*
xample, the molecular weight is an additive prop
ual to the sum of the weights of the atoms which for

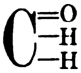
f the atoms within the molecule; physics, the study of equi-
nd the motion of the molecule itself.

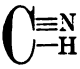
3. Equivalence.

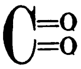
r chemical processes proceed in such a manner that one enters in the place of another in the molecule of a compound. called substitution (p. 6). The quantities of the elements olved depend upon their valence, which in the case of poly-lements denotes only a fraction of their atomic weight. But ie atoms are indivisible, the substitution can only proceed uch conditions that one atom of a bivalent element replaces ms of a univalent element, one atom of a trivalent replaces a univalent, or one atom of a bivalent plus one atom of a it. In other words, the sums of the atoms replacing one must be of equal value (equivalent). For example,


ane.


Chloroform.


Formaldehyde.


Hydrocyanic acid.


Carbon dioxide.

quantities by weight of the elements which show equal values lence) are called *equivalent* or *substitution weights*, and are ctions of the atomic weights corresponding to the valence given atoms. Therefore in the case of monovalent elements ivalent weights are equal to the atomic weights, in the case

(=2×126.8 parts) of iodine; therefore 2 atoms of io
of 1 atom of oxygen, or, since each atom of iodin
equivalent quantity of oxygen is $\frac{1}{2}$ atom=8 parts o

One atom of nitrogen=14.04 parts is equivalen
parts) of hydrogen, and therefore 1 atom (1.01 parts) o
alent to $\frac{1}{3}$ atom (=4.63 parts) of nitrogen.

The combining weights employed on p. 10 in e
of constant and multiple proportions are identical
weights discussed above, and were formerly used in
of the atomic weights. They are still of significance
(under which see Faraday's Law).

Properties of Molecular Aggregati

Those masses of matter which are capable
produced by aggregations of molecules. These
be of different kinds, which determines the state
the substance, i.e., its appearance in the solid,
condition.

The alteration of the state of aggregation of a
duced, not by the alteration of the state of the mol
but through the nature of the motion and the altera
of space between them. It is assumed that a
space exists between the separate molecules, and
gases this intermediate space is so large that the
selves are incomparably small in comparison witl
separates them. But since the molecular weigh
stances in the same states of aggregation unde
with a change of temperature (see Dissociation),
ble that at times the alteration of the state of aggı
panied by a change in the size of the molecule.

nd all liquids converted into solids. Many solid
alter their state of aggregation by an increase
thout undergoing a chemical decomposition. By
pressure liquids can pass over into gases, and, con-
rease in the pressure (within certain limits of tem-
an pass over into liquids.

es, as well as the atoms which compose them, are
ing in a state of constant vibration. The molecules
ces vibrate about a point of equilibrium, and on warm-
ons become quicker and of greater amplitude (expan-
substances), until finally the cohesion is so far overcome
longer retain the molecules in a position of equilibrium
ance becomes liquid (melts). In overcoming the cohe-
quantity of heat is used up (heat of fusion), so that
oint remains constant until all is melted. If the warm-
ued, then both on the surface (evaporation) as well as
iquid the motion of the molecules will be so increased
esion will be more and more overcome and the molecules
into the space above the liquid. Finally the motion
ecules will become so violent that they will entirely over-
ressure of the liquid and that of the air pressing upon this
uid will begin to boil, whereupon the temperature (boiling-
l remain constant until all is vaporized, since now all the
t (the heat of vaporization) is used up in the work of sever-
st bond of the force of cohesion.

at acts still further on completely gasified substances, the
ns of the atoms in the molecules can become so violent that
ecules split up into atoms or molecules of simpler constitu-
issociation, see Thermochemistry).

I. Solids.

ese have a characteristic appearance; within them the molecules
about a fixed point of equilibrium, vibrating or rotating.

ll solid substances occur organized (p. 4), crystallized, or amor-
s; many are known in both the latter forms, but possess in both
s different physical properties.

Very many substances, when they pass from the liquid, dissolved,
aseous state into the solid condition, assume a regular form bounded
planes; i.e., they appear as crystals.

Every crystallizable substance has a perfectly definite crystalline
rm which can facilitate its identification. If it separates from a

stal has the same form as the largest, and as they
ie forms of the crystals undergo no alteration.
ver, that the crystal form is regularly developed,
possible that in one and the same crystalline sub-
velopment of the separate planes can be different.
with the position of the planes with respect to
which the planes of every crystallized substance
are unalterable (law of the constancy of corre-
gles). In addition to their regularly bounded
a regular internal structure and (with the ex-
regular system) exhibit in different directions
ıysical properties with respect to cohesion, hard-
tivity of heat, and the transmission of light.
on rapid cooling, the crystals are disturbed in
at they grow through one another and a crystal-
The crystalline character of a body is determined
ich it can be determined from the surface of the
xture is laminated, radiated, or granular.
s no evidence of crystalline structure and breaks
ture, it is called amorphous. Amorphous sub-
physical properties in all directions within them,
to strongly supercooled liquids (p. 35), since
e obtained in an amorphous state if, while in
ey are cooled rapidly. The amorphous state
ble, and amorphous substances after standing
r spontaneously into the crystalline condition.

a. *Crystallography.*

forms is called crystallography. Many thousands
own, but they can all be referred to six classes
be accomplished by comparing the crystals ac-
ons of development, called axes, i.e., we imagine
passing through the middle points of the crystals,
l faces lie symmetrically about these axes. From
eir length and inclination, all crystals can be
ms.
all crystal forms of the six systems can be ac-
assumption of symmetry planes instead of axes.
tes a plane which can be imagined as so dividing
es that the one half stands in the same relation
one half stands to its image as seen reflected in
es between the six crystal systems are therefore

tric system: 3 axes of equal length, all at right
—9 planes of symmetry.
agonal system: 3 axes, 2 of equal length, the
ger or shorter, all at right angles to one another.
.

rimetric system: 3 axes of different lengths, all
nother.—3 planes of symmetry.
symmetric, or clinorhombic system: 3 axes of

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nd development of the separate planes can be different.
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tetragonal system: 3 axes, 2 of equal length, the
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netry.

or trimetric system: 3 axes of different lengths, all
ne another.—3 planes of symmetry.

onosymmetric, or clinorhombic system: 3 axes of

he vapor pressure, then these substances can be melted.
The pressure below which many solid substances no
ut pass directly into the form of vapor, is called their subl
ıre.

The transformation of a solid substance into vapor
ensation of the vapor into the solid state is called sublimat
separate volatile from non-volatile substances. The ord
ariations in the atmospheric pressure can be neglected in
eterminations.

After a substance has begun to melt, the quantity of
dded until all is melted (the heat of fusion, p. 33) does
ny increase in the temperature. In like manner a fuse
n solidification yields the same quantity of heat which it
elting without undergoing any reduction in temperatu
f solidification).

The heat of fusion or solidification is the number of he
hermochemistry) which are required in order to transfor
kilogram of a solid substance into liquid at the same
f the heat of fusion is multiplied by the molecular weight,
eat of fusion is obtained.

In regard to the alteration of the melting-point in mix
ubstances see p. 50. For the relation of the lowering of
oint to the molecular weight see p. 20, and for the relation
ng-point to the constitution of organic compounds see Part

c. Specific Heat.

f solid substances and its relation to the atomic and mole
ee p. 22.

d. Specific Gravity.

By dividing the atomic weight of an element by its sp
e obtain the atomic volume, i.e., the volume in cubic ce
upied by a quantity of the substance equal to its atom
essed in grams (gram-atom). For example lithium, a

also the the volumes of the
cular volumes are accordingly the space between them.
ers of atoms and molecules. the volumes which con-
ume, or specific volume, of a solid substance is the
by 1 gram of the substance, and is determined by divid-
cific gravity of the given substance. For example, the
of lithium is 0.59, i.e., 1 c.c. of lithium weighs 0.59
gram of lithium will occupy a volume of 1.69 c.c. (0.59
m Li:: 1 c.c.: x c.c.).

e. Optical Properties.

treated under liquids.

2. Liquids.

no fixed form, but assume that of the vessel which con-
eir molecules have no longer a definite position of equi-
ve a progressive motion in addition to one of vibration
o that each molecule is from time to time surrounded
ghboring molecules.

a. Boiling and Evaporation.

ooled to a definite temperature (freezing-point) all liquids
on being heated to a definite temperature (boiling-point)
porized. The latter is true only for such liquids as vaporize
mposition, but in the case of all liquids there is a definite
vapor even at temperatures below the boiling-point.
rmation of vapor takes place only at the surface of a liquid,
l evaporation; but if it proceeds also within the liquid, it is
g. The boiling-point is lower the lower the external pres-
n increase in the external pressure causes an elevation of the
nt.

liquid boils when the tension of its vapor equals the external
The boiling-point is always taken as that temperature at
tension of the vapor is equal to an external pressure of 760 mm.
Many substances which decompose when boiled under

unds see Part III.

b. *Specific Gravity.*

e calculation of the specific, atomic, and molecular volumes fro ecific gravity is carried out as in the case of solids (p. 36).

r the relation of the molecular volume to the constitution of organ unds see Part III.

c. *Spectrum.*

e property which many colored solutions have of absorbing a pa light split up by a prism. For the application of this property etermination of their chemical nature see p. 45.

d. *Refraction of Light.*

ery transparent substance possesses a definite power of refracti and the quotient of the sine of the angle of refraction (r) into t f the angle of incidence (i), called the coefficient or index of refra (n), is a constant for every given substance. $\frac{\text{Sine } i}{\text{Sine } r}=n$. This eat assistance in identifying a substance and for determining i y. It is, however, dependent on the density (specific gravity, e given substance (also on the pressure and temperature), as w its state of aggregation. By the use of the formula $\frac{n^2-1}{n^2+2}\cdot\frac{1}{d}=R$ R is obtained which for liquids and gases is dependent only chemical constitution. This is known as the specific refracti r or specific refractive constant.

ne product of the specific refractive power of an element with ic weight is called its atomic refraction.

ne product of the specific refractive power of a compound wi olecular weight is called its molecular refraction.

om the specific refractive power of a liquid mixture (i.e., a solutio the specific refractive power and the constitution of one of the su es is known, that of the other can be calculated. On the ot in a liquid mixture of several substances of known refracti the proportions by weight in which the different substances nt can be calculated from the specific refractive constant of at the end, where it is allowed to expand suddenly, and then cooled by expansion it flows back again through the outer pipe to the compressor. By this process the gas entering through the inner tube is cooled, the cycle beginning anew at the pump, until finally after repeated cooling and expansion in the apparatus the temperature falls to the critical temperature and liquefaction commences.

Many gases are supplied to the trade strongly compressed or liquefied in wrought-iron cylinders, which under these conditions are attacked very little or not at all by the gases within them.

b. Volume Relations.

The volumes of all gases at any given temperature vary inversely with the pressures to which they are subjected, and with unvarying pressure undergo an expansion of $\frac{1}{273}=0.003665$ of their volume at 0° for every increase in temperature of 1° and a corresponding contraction for every decrease of 1° in temperature. For the explanation of this behavior by Avogadro's hypothesis see p. 16.

Gases follow the laws of pressure and warming only when in a dilute condition; strongly compressed or cooled gases show more or less marked deviation from the laws, according to whether by pressure or cooling they can be more or less readily converted into liquids; that is, they show these deviations when near to their transformation into the liquid state.

These variations lead to the conclusion that as the molecules come closer together their own volumes become of greater moment and the attraction of one for the other (cohesion) can be no longer neglected. As a result of this mutual attraction the pressure necessary to produce a given compression is lessened, and this reduction of the pressure is found to be directly proportional to the square of the density, and inversely proportional to the square of the volume (Van der Waals' theory).

In the ordinary chemical operations gases are not weighed but, since it is more convenient, their volume is measured, and from this their weight is calculated. Since the volume of a gas is dependent on the atmospheric pressure and temperature (p. 15, 1), as well as on the water vapor which it carries (see Water), every measured gas volume (V) must be reduced to the normal volume (V_0) which the dried gas would occupy at 0° and a barometric pressure of 760 mm. This normal gas volume is often merely a mathematical assumption, since many substances can no longer exist as gases at 0°. The reduction is carried out by means of the following formula: $V_0=\frac{V(B-W)}{760(1+0.003665T)}$, in which 0.003665 is the coefficient of expansion of gases (p. 15, 1), T the observed temperature, and B the observed pressure (height of barometer) in millimeters. Since the removal of water vapor is inconvenient, the gas to be measured is brought in contact with water in order that it may become completely saturated with water vapor, and then from the observed pressure in millimeters (B) a quantity is subtracted equal in millimeters to the tension of aqueous vapor at the temperature of observation.

The most important quantities, with relation to the volume of a gas, can be calculated from the knowledge of its molecular weight and the weight of a liter of oxygen (=1.429 grams).

d. The cause of this reversal of the spectra
aw: A gas or vaporized substance absorbs all
e periods of vibration as those which the sub-
while it is transparent to all other light rays,
conditions the absorption spectrum of a sub-
s emission spectrum. The dark lines which
he self-luminous heavenly bodies are explained
be assumed that these bodies consist of an in-
nucleus surrounded by glowing gases or vapors.
ption spectra of the heavenly bodies with the
ments it is possible to determine what elements
of the different heavenly bodies. If the direct
n is cut off, as is the case in a total eclipse, then
ned is that of the glowing gases surrounding
ts of bright lines corresponding to the different
solar atmosphere.

action and Rotation of Light.

er liquids.

4. Physical Mixtures.

e name applied to a physically and chemically
different substances which cannot be separated
purely mechanical means. Physical mixtures,
ompounds as well as mechanical mixtures, have
and are produced by a uniform mixing together
different substances constituting the mixture.
constituents is therefore more or less difficult,
nical mixtures, whose constituents can readily

ithout reference to their actual state of aggre-
s solutions, and are accordingly distinguished
solid solutions. They occupy an intermediate
ical mixtures and chemical compounds.

Diffusion and Osmosis.

olutions, or gases are brought into contact a
xing takes place until the composition of both
omenon is known as diffusion.
f liquids is determined by their nature, all gases
ct can mix in every proportion without relation
the gases. If, for example, a vessel containing
ed by one containing hydrogen, although the
y-two times heavier than the hydrogen it will
e hydrogen and the latter will work downward
ture of the two becomes perfectly uniform and
of diffusion of a gas is inversely proportional
lensity, so that, for example, the rate of diffusion
n times as dense as hydrogen, is only one-fourth

covered with a lighter one with which it is mis-

finally, after the removal of the separated material
stant composition is obtained. This mixture always
point than the original mixture, and on further fusi
this melting-point remains constant and the mixture d
in composition. Such a mixture is called a *eutect*
hydrate, and the temperature at which it commences
a *eutectic point*.

e. Liquid Solutions.

These are the solutions in a restricted sense, an
liquids combine with either gases or other liquids
new, entirely homogêneous liquid having new prope
The solubility is different and usually limited f
substances in the same solvent and for the same s
different solvents. It is dependent on the tempera
in the case of gases, on the pressure. Indeed the s
pound can have a different solubility according to i
lization. The greater number of inorganic compo
in alcohol, while carbon compounds are mostly sol
ether, and their solubility decreases with an increasin
Solutions closely resemble chemical compounds; c
of the dissolved substance with the solvent often s
for example, many anhydrous salts separate from
tions with water of crystallization.
A more or less complete separation of the constitu
tions can be effected by distillation.
When a liquid is converted into vapor and the va
by cooling the process is called *distillation*. In th
gases are given off entirely or partially (p. 53) an
are left behind.
Rectification is the repeated distillation of a liqu
of completely freeing it from admixtures.
Dry distillation is the decomposition of non-vo
pounds by heat out of contact with the air, as a re
liquid, and gaseous decomposition products are obt
Fractional distillation, see p. 53.
A solution which contains so much of the dissol
under the given conditions the solvent can take up

re. The power of liquids to dissolve gases
ease in temperature, but also on the solidi-
issolved gases are set free. Liquids which
quids or solids are able to dissolve gases
ing of gases soluble in water over hot water

of gases which dissolve are directly propor-
e gases during the solution process (Law of
in the case of very readily soluble gases,
tion usually occurs), so that 1 volume of a
eres pressure double the quantity by weight
Boyle's law, p. 15) of gas that would be dis-
ssure. If the pressure is reduced, then a
he gas is set free (foaming of champagne,
on of ammonia gas in water will give off
e in the space above the liquid has become
ric acid is now introduced into this space,
mmonia gas present, so that fresh quantities
by the solution until all the ammonia which
removed.

t that the total pressure which is exerted
l to the sum of its partial pressures—namely,
the gases alone exert—from a gaseous mix-
gas will be absorbed as corresponds to its
e, another gas is conducted through or over
e dissolved gas which has separated will be
ch its partial pressure will be constantly re-
issolved in the liquid will finally be entirely
ution of a gas is boiled, the vapor of the sol-
s of the dissolved gas which have separated
ntains any of the gas dissolved in it.

ons of Solids in Liquids.

y formed with the absorption of heat, since
ved substance are driven into the solvent
e solution pressure, and accordingly energy
drawn from the surroundings. The case is
of a liquid or a solid where the molecules enter
n with a certain pressure, the vapor pressure.
until the pressure of the vapor formed is
f the liquid, so a solid substance passes into
osmotic pressure of the solution comes into
n pressure of the solid substance. If, how-
part of the solvent to form a chemical com-
volved, since the quantity of heat which is
is greater than that required for liquefaction.
lcium chloride dissolves in water with the
mbines chemically with a part of the water.
chloride containing water of crystallization
ng.

is stronger the more rapidly the solution
the case of aqueous solutions when, instead

and above this temperature become again liquid. The g
loidal solutions are called geles or hydrogeles; they swe
in water by absorbing it, and many dissolve on the add
water (e.g., glue). They can dissolve crystalloids, but
and permit their diffusion (use of gelatine for bacteria c
graphic dry plates, etc.). The liquid colloidal solutions
soles; certain soles of the heavy metals, for example
gold, exhibit the properties of enzymes and are therefo
inorganic enzymes. Like organic enzymes, the action of
weakened by certain poisons.

RELATIONS BETWEEN ATOMIC WEIGHT AND PRO THE ELEMENTS.

If the elements are compared with one another wi
their properties and their compounds, it is evident t
be divided into groups or families, whose members sho
larity to one another. Other separate members of
show relations to other groups and thus form connecting
the groups. These relations of the elements are mos
pressed when they are arranged according to the magn
atomic weights, when it is found that the succeed
exhibit apparently irregularly increasing properties, bu
the passage of a given period, the chemical and physica

	GROUP I.	GROUP II.	GROUP III.
Hydrogen Compounds	Unknown	MH	MH_2
Highest Oxygen Compound	Unknown	M_2O	MO
Period. Series.			

ents suggests or indeed repeats that of the elements nem. *The properties of the elements are periodic atomic weights* (Periodic law). If the elements are ording to the magnitude of their atomic weights ar elements which recur after certain periods stand other, then these vertical rows form the groups or the horizontal rows contain the periods, that is, hose atomic weights lie between the successive mem- nily. The arrangement of the elements according to called the periodic or natural system of the elements in the table below. In this the elements fall into onsisting of ten rows, and in eight groups, of which the eighth each forms a side group as indicated by a splacement to the right of certain of the elements in- vertical rows. In this way those elements of a group the greatest similarity to one another are brought to- periods are distinguished as large and small periods the number of elements which are contained in them. s of every group (vertical row) show differences between weights which closely correspond to those between the hts of the other groups, and the same is the case in the izontal rows).

iodic system makes it possible to divide the elements ively, to check the accuracy of the atomic weight deter- nd to predict the existence and properties of elements till undiscovered.

	GROUP VI.	GROUP VII.	GROUP VIII.
	MH_3 M_2O_5	MH_2 MO_3	MH M_2O_7
	Nitrogen 14	Oxygen 16	Fluorine 19
8	Phosphorus 31	Sulphur 32	Chlorine 35
	Vanadium 51	Chromium 52	Manganese, etc., 55
01	Arsenic 75	Selenium 79	Bromine 80
	Niobium 94	Molybdenum 96	Ruthenium, etc., 102
	Antimony 120	Tellurium 128	Iodine 127
	—	—	—
	Tantalum 183	Tungsten 184	Osmium, etc., 191
	Bismuth 208	—	—
	—	Uranium 239	—

ium, etc. =Osmium 191, Iridium

'he elements standing below one another in these subgroups for y similarly constituted compounds.

Lanthanum, etc. =Lanthanum 138, Cerium 140, Praseodymium 14 dymium 144.

Samarium 150, Gadolinium 156, Erbium 166, and Thulium 171 ca be satisfactorily inserted in the system.

Among the physical properties of the elements which show a dire ation to the atomic weight are included the specific gravity and atom ume (p. 36), the extensibility, fusibility, and volatility, the speci ractive power, the specific heat, the conductivity for heat and ele city, and the electrochemical character. All of these properties sho maximum or minimum in the middle of the periods (horizontal rows or example:

Third Period.	K	Ca	V	Cr	Mn	Fe	Co	Ni
p. gr.	0.87	1.6	5.5	6.8	7.2	7.9	8.5	8.
tomic vol.	45.40	25.2	9.3	7.7	6.9	7.1	6.9	6.
Ielting-point.	62°	760°	3000°	3000°	1900°	1800°	1800°	160

Third Period.	Cu	Zn	Ga	Ge	As	Se	Br
p. gr.	8.8	7.1	5.9	5.5	5.6	4.5	2.9
tomic vol.	7.2	9.0	11.6	13.1	13.2	17.5	26.9
Ielting-point.	1100°	420°	30°	900°	500°	217°	−8°

In the case of the elements of many groups (vertical rows) the spec ravity, the fusibility, etc., increases with the atomic weight. For exam

Second Group.	Li	Na	K	Rb
ìp. gr.	0.59	0.97	0.87	1.5
Ielting-point.	180°	96°	62°	38.5°
Boiling-point.	900°	740°	670°	500°

Third Group.	Be	Mg	Zn	Cd
Sp. gr.	1.8	1.7	7.1	8.6
Ielting-point.	1000°	700°	420°	320°
Boiling-point.	1600°	1300°	950°	750°

In the successive periods (horizontal rows) the elements contin more metallic character; the first period contains 2 m

II. AFFINITY.

CHEMICAL AFFINITY.

The study of affinity includes the study of chemical mechanics the transformation of chemical energy into mechanical energy ume, surface, and motion energy), or into non-mechanical energy t, electric, and radiant energy).

In chemical reactions the production or absorption of heat, elec- ity, or light takes place, and these different sorts of energy are duced from all or a part of the chemical energy. Conversely, t, electricity, and light are often the cause of chemical reactions, and ing their progress an equivalent transformation of the given rgy into chemical energy takes place.

Chemical energy is the most complex of all forms of energy and least understood, and the only method by which it can be more ely investigated is by transforming it into other forms of energy, s simplest to transform it into heat.

The knowledge of the actual nature of chemical affinity is at pres as unfathomable as that of gravity, but great progress has been le in the study of its action, as well as its dependence on mass perature, and pressure. The consideration of the different form hemical reactions leads to the conclusion that the assumption of e of affinity considered as a force of attraction is not only o e advantage in explaining chemical reactions, but is often directly trary to experience.

For example, when water (H_2O) acts on glowing iron (Fe), ferro

attractive forces has therefore been
it has become usual to consider the
built up from them, as *actively moving*
another are determined by the form
inetic nature of affinity).

L MECHANICS.

of the rate or velocity of chemical
dynamics) and the equilibrium rela-
the progress of chemical reactions

system of bodies strives to approach
f energy which can be transformed
) is as small as possible. Chemical
place spontaneously on bringing the
ample, arsenic and chlorine combine
hloride.

reaction often requires the action
as heat, electricity, or light. This
ical energy, since a part of the mole-
o atoms, or the union of the atoms
evered before the chemical reaction
been started in this manner, then it
emical reactions which proceed with
other hand, energy must be con-
e the reaction stops.

kinetics and also chemical statics are
action (law of Guldberg and Waage),
reacting substances and the tempera-
chemical action of a substance taking
portional to its active mass (likewise the
he quantity contained in unit volume;
m-molecules of the reacting substances

n of many substances does not there-
substances, when the existing con-
formed substances can likewise act
, if the two compounds AB and CD

i.e., in the number of substances which take part in the
ince A has affinity for B as well as for D. Since thes
ct simultaneously, the system comes into equilibrium wl
uantities of the four possible compounds have been form

The law of mass action shows the signification of the co
f substances on the progress of chemical reactions, lays the
or the investigation of chemical statics and dynamics, and
ignificance, since with the help of this law, with proper co
f the nature of the substances involved, the temperature an
t is possible to deduce mathematically the relations betweer
ities of the reacting substances and their action and to reach
onclusions in respect to the velocity of reactions and in respect
quilibrium.

1. Chemical Statics.

Chemical statics treats of the equilibrium relations w
after a chemical reaction has proceeded for a certain peri
according to the law of mass action, the tendency with wl
stance strives to undergo transformation increases with
tration, therefore in a chemical reaction, as a result of tl
in the original substances, their tendency to transformatic
constantly weaker, and on the other hand, as a result of t
in the products, their tendency to produce retransformati
constantly greater; finally, in this way the mutual action
stances will cease, since now the products, in the quantiti
they have formed, will have a tendency to again rep
original substances. The chemical reaction therefore c
standstill before it is completed, that is, the system reac
of equilibrium.

Every such state of equilibrium is really not to be

spective of whether the reaction starts with the original subst
or with the final products.

Those reactions which lead to the same final states, whether
start with the original substances or with the products, are ca
reversible reactions. They are denoted by substituting the symb
for the symbol = in the equations representing the reaction.

If, for example, an alcohol is mixed with an acid, an ester and wa
are formed, but a part of the alcohol and the acid always remains u
altered (provided that neither the acid nor the alcohol are present in ve
great excess, p. 62) no matter how long the action is permitted to co
tinue. The quantities of ester and water which will be formed are de
pendent on the original quantities of alcohol and acid taken, and approac
a certain limit which is different for every different mixture. The same limit is reached when an ester and water are brought together in a proportion which is equivalent to that of the alcohol and acid. For example:

$$\underset{\text{Acetic acid}}{CH_3COOH} + \underset{\text{Ethyl alcohol}}{C_2H_5OH} \rightleftarrows \underset{\text{Acetic ester}}{CH_3COOC_2H_5} + \underset{\text{Water.}}{HOH}$$

If finely divided, glowing iron (Fe) and water vapor (H_2O) are allowed to act on one another in an enclosed space, an equilibrium system results which always contains iron and water vapor in addition to ferro-ferric oxide and hydrogen: $3Fe+4H_2O \rightleftarrows Fe_3O_4+4H_2$. The same system of equilibrium is obtained when glowing ferro-ferric oxide and hydrogen are heated in a closed vessel.

However, a chemical reaction does not only proceed to a state of equilibrium, but is complete, if through the mutual action of the reacting substances there are formed insoluble or volatile substances, since in such cases the given products are removed from the sphere of action, so that the same reaction which causes the formation of the first quantity of insoluble or volatile substance can again take place until the reaction is complete.

When sodium bicarbonate ($NaHCO_3$) is heated, it is converted completely into sodium carbonate (Na_2CO_3) if the carbon dioxide (CO_2) which is formed can escape: $2NaHCO_3=Na_2CO_3+CO_2+H_2O$. However, if the carbon dioxide is prevented from escaping a state of equilibrium is reached, since sodium bicarbonate will be again partially reformed:

$$2NaHCO_3 \rightleftarrows Na_2CO_3+CO_2+H_2O.$$

If water vapor is allowed to act on glowing iron in an open tube so that the hydrogen formed can escape, then no state of equilibrium is reached, but the reaction is complete: $3Fe+4H_2O=Fe_3O_4+4H_2$. The case is the same when hydrogen is allowed to act on glowing ferro-ferric oxide: $Fe_3O_4+4H_2=3Fe+4HOH$, since in this case the resulting water vapor can escape (above). The quantities of solids present in a system exert no influence on the final state of equilibrium, since the alteration

their saturated solutions are dissolved in greater
ease in pressure if the total volume of the salt and
er necessary to dissolve it is greater than the volume
ition.

the first order, namely, that in which only one sub-
) is present, from the physical standpoint is that
nt states of aggregation of a substance, e.g., between
apor, between ice and water and water vapor; from
dpoint it is that which occurs when complex mole-
simple molecules of similar composition, e.g., $N_2O_2 \rightleftarrows 2NO$.
of the second, third, etc., order, namely, when two,
stances (constituents) are present, from the physical
e equilibrium between two, three, etc., substances which
ysical mixture (p. 46) with one another, e.g., the mixture
etc., gases or liquids with one another, the solution of
solid substances in a liquid; from the chemical stand-
ilibrium which occurs from the action of two, three, etc.,
one another.

nces or components of a chemical equilibrium not all atoms
mplexes can be considered as the same, but only the smallest
hose of which all the bodies taking part in the equilibrium
ed. Therefore the system $N_2O_4 \rightleftarrows 2NO_2$ has only one com-
e system $CaCO_3 \rightleftarrows CaO + CO_2$ only two components. As a
e for any given system as many components are to be taken
nber of members of the system minus one.

geneous equilibrium is that in which all the components
ysically and chemically homogeneous system, e.g., as gases,
liquids, as solutions, etc. This form of equilibrium exists
gaseous chemical systems $H_2O \rightleftarrows H_2 + O$ and $N_2O_4 \rightleftarrows 2NO_2$,
liquid chemical system $C_2H_5OH + CH_3COOH \rightleftarrows CH_3COOC_2H_5 +$
p. 61).

existence of solid solutions (p. 49) and the power possessed
ds to diffuse into other solids (p. 46) allow the assumption that
ogeneously solidifying mixtures (e.g., in alloys) a condition of
chemical action and final equilibrium can exist, although in
ases the chemical action proceeds so slowly that it has been im-
le to measure it except in certain individual cases.

eterogeneous or non-homogeneous equilibrium is that in which
omponents are present in different states of aggregation and
form a heterogeneous system. It is represented by the chemical
m $CaCO_3$ (solid) $\rightleftarrows$ CaO (solid) + CO_2 (gas), and further by the
ical systems KNO_3 (solid) $\rightleftarrows$ KNO_3 (dissolved), H_2O (liquid) $\rightleftarrows$ H_2O
or), H_2O (solid) $\rightleftarrows$ H_2O (liquid).

ondensed equilibrium is that form of heterogeneous equilibrium
hich no gaseous components are present, or if present can be
ected.

The chemically and physically homogeneous parts of which a heterogeneous system is built up are called *phases;* they can be mechanically separated from one another and the separate phases can be physical mixtures as well as chemical substances.

For example, the system Water + Water vapor consists of two phases, the system Ice + Water + Water vapor of three phases, the system $CaCO_3$ (solid) $\rightleftarrows$ CaO (solid) + CO_2 (gas) of three phases, the system $3Fe$ (solid) + $4HOH$ (vapor) $\rightleftarrows$ Fe_3O_4 (solid) + $4H_2$ (gas) of three phases, since the water vapor and the hydrogen gas, like all gases, constitute only one phase, since they represent in all parts chemically and physically homogeneous mixtures.

The degree of freedom stands in a definite relation to the phases of a heterogeneous system. By degree of freedom is understood the conditions (i.e., pressure, temperature, and volume relations), which can be optionally chosen without thereby altering the equilibrium of the system. For example, the system Water + Water vapor, consisting of two phases, has one freedom, namely, either the pressure or the temperature can be chosen as desired without altering the system. If the pressure is fixed then the system can exist only at a perfectly definite temperature, if the temperature is fixed then the system can exist only at a perfectly definite pressure. The system Ice + Water + Water vapor, consisting of three phases, has no freedom and can therefore exist only at a perfectly definite pressure (4.6 mm.) and a definite temperature (+0.007°).

Also every elementary substance has two freedoms for every state of aggregation, i.e., of its three variable quantities, pressure, temperature, and volume, two can be altered as desired without changing the state of aggregation.

Every system of equilibrium consisting of one component has with two phases one freedom, with three phases no freedom; for every further component the number of freedoms increases by one; therefore the system $CaCO_3 \rightleftarrows CaO + CO_2$, consisting of two constituents (p. 62) and three phases (above), has one freedom. Hence follows the phase rule of Gibbs: *Equilibrium exists when the sum of the phases* (P) *and the degrees of freedom* (F) *of a system is equal to two more than the components* (B) (see p. 63), that is, when $P+F=B+2$.

With the assistance of the phase rule, the number of degrees of freedom on the one hand, and the number of phases on the other, which for the given components of a system must be present in a state of equilibrium, can be readily calculated beforehand, since $F=B+2-P$ and $P=B+2-F$. From the latter it follows: If a heterogeneous system is in a state of complete equilibrium then one phase more must be present than the number of the components, if more phases are present then equilibrium of the separate phases is only possible at a definite temperature, pressure, and concentration. If less phases are present, then the equilibrium is incomplete.

All systems of equilibrium with equal degrees of freedom show complete agreement in their behavior if the factors (i.e., pressure, temperature, or volume), which influence the equilibrium, are allowed to continuously alter. Since the degree of freedom can be calculated with the help of the phase rule, this rule also serves for dividing systems of

y moment is proportional to the product
ctive mass) of the still undecomposed original
coefficient of velocity, which, however, has a
di-, tri-, etc., molecular reactions (i.e., for reac-
ered r proceeding from one, two, three, etc.,
icient of velocity it can be determined
ecular or dimolecular or trimolecular, etc.
n correct that the decomposition of arseniu-
olecular reaction, since the separated arsenic
at least four atoms in the molecule (p. 21):
determination of the velocity coefficient gives
s to a monomolecular reaction. The reaction
follows: $AsH_3 = As + H_2$, so that each molecule
nd then two hydrogen atoms combine to form
he unknown number of arsenic atoms combine
le of the solid arsenic.

proceeds only to a state of equilibrium, then
of reaction must have become equally great
m, namely, in this state the original substances
bine just as fast as the products react on each
l materials. For example, if one gram-molecule
d are mixed, then a state of equilibrium results
ds of the total quantity of ethyl acetate, which
he reaction was complete, has been produced.
velocity of the transformation of the original
ltaneous transformation of the products can be
cess can be considered as if the opposed reactions
ly of one another (principle of coexistence); the
velocities can be measured, since it must corre-
with which the reaction approaches the state of
he chemical change observed in every moment of
hange in one direction diminished by the change
, therefore by determining this difference the dif-
ies of reaction can be arrived at. For example,
l acetate formed in every moment of time from
alcohol can be measured, and likewise the quantity
acetic acid formed from ethyl acetate and water.
of the quantities formed in both cases the product
ction can be calculated.

THERMOCHEMISTRY

elation between chemical energy and heat:

1. General.

ations of chemical energy into other forms of
rmation into heat proceeds the most readily.
sorption of heat (and often at the same time of
) accompanies all chemical reactions.

est quantities of heat are set free, but the quantity
also on the change in the state of the substances whic
given chemical process. Therefore the quantity c
or absorbed in a chemical process cannot, as was f
serve as a measure of the affinity of the given substa

According to whether heat is produced or absorl
reaction the reaction is called *exothermic* or *endoth*
a substance is called exothermic or endothermic acc
in its formation heat is set free or absorbed. Ex
are positive heat reactions, endothermic are negativ
The heat is measured in heat-units or calories, a larg
being the quantity of heat required to warm 1 kilog
a small calorie (=cal.) the quantity of heat require
of water 1°.

In order to allow the simplest comparison the heat
on the basis of the gram-unit, but on the basis of
corresponding to the number of atoms which combin
cule. The heat values are mostly based on the state
stances exist at 18°

The heat is distinguished as the heat of solution, t
the heat of formation, the heat of decomposition, th
zation, and the heat of combustion; further, as the
(i.e., the heat which results on the combination of
definite number of water molecules) and as the heat c
the heat which results from the splitting up of a disso
its ions). The heat calculated on the basis of the gr
given substance is called the molecular heat of solut
tion, etc.

The mixing-calorimeter is used in measuring th
solutions. It consists of a vessel of metal or glass
ing substances are mixed, their temperature havi
measured beforehand. The quantity of heat is c

Equations which include the energy set free
in the form of heat, are called thermochemical equations.
The evolution of heat which accompanies a chemical proc
ays the same whether the process takes place in one step or wh
asses through a number of intermediate processes (Law of Hes

For example, on dissolving 39 grams of potassium in 36.4 gra
solved hydrochloric acid a quantity of heat equal to 61.8 C
olved, and the final result is the same whether the process takes
one step: $K+HCl=KCl+H+61.8$, or whether it takes place in
ctions: $K+H_2O=KOH+H+41.8$ Cal. and $KOH+HCl=$
$O+13.7$ Cal. The law is very important, since it makes it po
calculate the heat in many cases where it cannot be deter
rectly; for example, the heat of formation of carbon monoxide
26.3 Cal. is deduced from the combustion of carbon to carbon dio
$+2O=CO_2+94.3$ Cal., and from the combustion of carbon mon
o carbon dioxide: $CO+O=CO_2+68$ Cal.; therefore 94.3 Cal. − 68
6.3 Cal.

In many chemical reactions there is a tendency to produce
ubstances whose formation is accompanied by the evoluti
he greatest quantity of heat (principle of maximum work).
xample, in a system consisting of potassium+chlorine+br
otassium chloride (KCl) and not potassium bromide (KBr) is fo
ince $K+Br=KBr+90$ Cal.; $K+Cl=KCl+106$ Cal.

Accordingly, a chemical reaction generally takes place more
the resulting products have an opportunity to enter into a
eaction, since in this case a greater quantity of heat is produce
xample, chlorine decomposes water only very slowly: H_2O
$HCl+O+10$ Cal.; but if the oxygen can immediately exert a
hemical action (as is the case, for example, in the presence of
ioxide (SO_2), then a rapid decomposition of the water take
$H_2O+2Cl+SO_2=H_2SO_4+2HCl+74$ Cal.

The principle of maximum work has not the universal ap
to it; it applies to such reactions as

to the splitting up of the mole-
ces into simpler constituents which takes
rable conditions. Dissociation exists only
ing influences are acting; when they cease
s again combine to form the original sub-

between the thermal dissociation produced
short is called dissociation, and that which
of certain substances, the electrolytes, which
and hydrolytic dissociation (p. 77).
does not appear suddenly in the whole
substance, but begins gradually, and steadily
ng temperature. With decreasing tempera-
of the dissociation products proceeds simi-

en and oxygen begin to combine to form water
it at 1200° a splitting up of the water into the
At 2500° half of the water is dissociated and
temperature all of the water is split up and the
by side, as at 200°. If the temperature is now
of water again takes place: $H_2O \rightleftarrows 2H+O$, and
have again completely combined with one another.
drous sulphuric acid (H_2SO_4) even at 40° begins
ur trioxide (SO_3) and water (H_2O); this dissocia-
6°; on cooling the combination of the dissociation
akes place.

phenomena constitute a class of reversible reac-
at constant pressure (see below) for every given
degree of dissociation of a substance is perfectly
a definite state of equilibrium exists between the
bstance present and its decomposition products.

sel filled with hydrogen iodide (HI) is heated to 518°,
of the gas dissociates into $H+I$. If quantities of $H+I$
their atomic weights are heated in a closed vessel to
cent. of the gaseous mixture remains uncombined, while
ransformed into HI gas: $2HI \rightleftarrows 2H+2I$.

iation takes place with an increase in volume, which
se, then it is dependent on the pressure as well as on
e. If the pressure is increased the dissociation de-
pressure is lowered then the dissociation increases.
pressure (the dissociation pressure or dissociation

n. but allotropism exists also when (as in the case phosphorus, and carbon, which see) the different given element contain a different number of atoms somerism, as is known in the case of the carbon com-), also occurs when the atoms which form the mole-nd have a different arrangement (p. 30) or when the are whole multiples of one another.

do not act on water can combine to form free mole-ectrodes, since after giving up their electric charges er repel each other, and likewise metal ions whose onsist of one atom) can form unelectrified, monatomic, ules. For example, two negative chlorine atoms will o form one chlorine molecule, two negative hydroxyl ions bine to form one H_2O_2 molecule, one positive copper ion will er into a copper molecule, etc.

e fact that the electrically oppositely charged ions do not alize their electricities in solution can be explained by the mption that their number is very small as compared to the ter molecules which lie between them, so that the latter acts an insulator, and this action is greater the more the quantity of ater (or the quantity of other dissociating liquid) exceeds that f the electrolyte. Therefore in concentrated solutions the possibility that the electrified ions will combine to form non-conducting, and therefore non-dissociated, compounds is much greater, since in this case they are not so widely separated from one another.

The transportation of the electricity supplied to the solution by the electrodes is carried out by the movement of the electrically charged ions to the electrodes. Since, for example, the positive ions are attracted by the negatively charged electrode and therefore move towards this and give up their electricity to it, they can no longer exist as ions, but separate at the electrode as atoms or groups of atoms. The negative ions undergo a similar change at the positively charged electrode. As a result of this giving up of electricity at the electrodes the solution receives at each of these points an excess of electricity with which the electrodes are charged, and this electricity moves with the repelled ions (namely, the ions which carry electricity similar to that of the repelling electrodes) through the liquid to the other electrode.

Since it is exclusively the free ions which conduct the electricity, therefore with an increase in the ions, such as is produced by the in-

going process a salt was actually formed in the solution,
neutralization would correspond to the heat of formati
salt (which has a different value for different salts).
dilute solutions of different neutral salts are mixed (wh
precipitate one another), there is no thermal effect pr
thermal neutrality); which shows that the ions of the
remain side by side uncombined in the solution, namely
no change in condition takes place. A dilute solution of
of $NaNO_3 + KCl$ are therefore identical and both contain
$NO_3' + K^{\cdot} + Cl'$.

Neutral salts of weak acids can show alkaline reacti
solutions, salts of weak bases can show acid reacti
result of the hydrolytic dissociation, i.e., dissociat
action of the ions of water, as a result of which the
acids on the one hand split up into non-dissociating (
ing) acids and dissociated bases, on the other hand t
weaker bases split up into undissociated (not all
bases and dissociated acids.

The electrical conductivity of absolutely pure wate
tremely slight but still measurable, shows that even w
dissociated into its ions $H^{\cdot}$ and OH' (p. 78). These ion
bine with the cations and anions produced on dissolvin
in water to form undissociated acids or bases, since the slig
acids and bases require no more $H^{\cdot}$ or OH' ions to preve
tion than are present in the water. Small quantities o
sufficient to cause a partial re-formation of acid or bas
other hand the stronger acids and bases remain dissocia
sponding acid or basic reaction must appear.

For example, potassium cyanide, KCN, a salt of t
cyanic acid HCN and the strong base KOH, when dis
exhibits the alkaline reaction of the OH' ions and the ch
of undissociated hydrocyanic acid, although the $K^{\cdot}$ ions
trolytic dissociation do not react alkaline and the CN' ion

H ions of the water are present in the solution
these cannot combine with one another because
te, while the OH' ions of the water are used up
ase $Fe(OH)_3$ with the $Fe^{\cdot\cdot\cdot}$ ions, this base being
cely dissociated.

on of water increases with the temperature, on
ic dissociation increases also.

ation is also called hydrolysis, but this must
the term applied to the splitting up of the
ted, non-electrolytic, organic compounds into
h the simultaneous addition of the elements
, called hydrolysis.

ficial dyes which undergo a change in color by
acids or bases, and which therefore serve for the
bstances as well as for demonstrating neutraliza-
d *indicators*. These indicators are weak acids
different color when they are dissociated from that
n undissociated. Since only weak acids or bases
it up into ions, while their neutral salts are very
, therefore on the addition of the slightest quan-
e the formation of a dissociating salt immediately
of the indicator immediately undergoes an altera-
itmus is a weak, red acid which is colored blue by
e), since the resulting salt immediately dissociates
the base and the blue anions of litmus acid. If
ates more readily than litmus be added, then the
convert the blue litmus anions into undissociated,
ciated phenolphthalein is a weak, colorless acid
by traces of bases, because the resulting salt im-
nto metal cations and red anions of phenolphthalein.
re readily dissociating acid convert the latter into
s phenolphthalein again.

on of Chemical Energy into Electrical Energy.

l best known chemical systems in which the
th chemical phenomena is converted into elec-
galvanic elements or voltaic cells. These are
ductors of the first order (metals or carbon)
he second order (electrolytes) from which an
tained.

electrolytes that the conduction of the current
mical reaction, therefore all galvanic elements
tes which up to the present have been em-
ely dissolved in water or fused.

TOCHEMISTRY

between chemical energy and radiant

emical Energy into Radiant Energy.

accompanied by the development of
(see Oxygen). In this process a part
reacting substances is set free as heat
first appears as heat which raises the
so high that they radiate visible light.
the direct transformation of chemical
, as is illustrated by the brilliancy of
erature of which is only about 1350° but
)° if the enormous development of light
re alone. The light produced by self-
, bacteria) also depends on chemical
no elevation of temperature.
ith a flame, many only with glowing;
ndescence by the combustion process and
ces burn with a flame which are com-
elop combustible gases from their own

and iron burn only with incandescence since
ses. Wood, coal, tallow, etc., burn with a
t of the heat they produce gaseous, com-
cts.

us or non-luminous; the luminosity is
ncandescent solid substances in the flame
he temperature and density of the burning

an become luminous when solid, non-volatile
nto it (for example, the Welsbach light) and
ninous when the products of combustion are
nc and magnesium burn with luminous flames
they form on burning are not volatile and
eated to a white heat in the flame. When
ompressed together they burn with a luminous
of the flame-gases is then greater.
ly burn with a luminous flame are cooled they
power and, *vice versa*, non-luminous gases
they are previously warmed. For example, if

by the non-combustible gases added.

Many substances which burn in the air with a non-lun
burn in pure oxygen with a luminous flame, since in the lat
flame is not cooled by the inert nitrogen of the air and there
a higher temperature and further because the products of
in vessels cannot escape so rapidly with the removal of he
open air.

The luminosity of the ordinary illuminating materials i
fact that finely divided carbon separates out in them an
to a white heat. This can be demonstrated by holding a
in the flame and observing the carbon which is deposited o

In the Welsbach light a fabric composed of 99 per ce
and 1 per cent. cerium is heated in a non-luminous flam
descence.

The flame of marsh-gas (CH_4) is non-luminous; the flame
(C_2H_2), on the contrary, is very brilliant because it contains tw
carbon in the molecule as the former, and this great quantit
if too much oxygen does not reach the flame, does not burn
but separates out in a finely divided state and becomes whit

Marsh-gas, hydrogen gas, and carbon monoxide gas bur
luminous flames because their products of combustion are
of a gaseous nature.

Flames consist of an envelope of glowing gas, while in
of the flame (because of a lack of that gas which surroun
and maintains it) no combustion and accordingly no high
can exist; the interior of the flame consists of unburned
cold.

The ordinary, luminous flame consists of three parts: th
part consists of the gases still unburned (hydrocarbons, espe
lene) which are formed from the decomposition of the wa

he different flames are very different and
inosity, as is shown by the hardly visible
ater).

of air is introduced into the interior of an
, because of the complete combustion of the
the dilution (p. 92), the flame becomes non-
of the flame, however, becomes noticeably
he construction of the Bunsen burner used in
ture of gas and air is burned.
e, a metal tube through which air is blown
directs this sidewise upon the object to be
ame principle. This has an oxidizing action
uter part of the flame, since an excess of oxy-
educing action of substances held in the inner,
contains free carbon or reducing hydrocarbons.

coloration to a non-luminous flame (since
and reduced by the flame and the metal
seous state), which is characteristic for the
. For example, the salts of sodium color
lts of potassium color it violet, the salts of
etc., so that in this manner many elements
compounds. If, however, a number of ele-
flame are present, then the color of one ele-
f another, but in such a case all of the elements
from the spectra of their gases (p. 44).
out rays of definite wave length depending
of the given gas, but which are independent
ithin wide limits, and which show character-
p by a prism (p. 45).

on of Radiant Energy into Chemical Energy.

gy of light can cause chemical changes which
mical reactions. Radiant energy shows con-
electrical energy; for example, the metals are
ly electrified in ultraviolet light, and the action
enium and phosphorus into modifications which

eactions are exothermic or endothermic; in the
rgy is consumed, but is set free as heat) the light
rt the chemical process and to accelerate it in the
ic agent; in the latter case, at all events, the energy

PART SECOND.

INORGANIC CHEMISTRY.

DIVISION OF THE ELEMENTS.

ORDINARILY the elements are divided into two groups, the *non-metals* or *metalloids* and the *metals*.

The *metals*, when compact, have the well-known metallic appearance and are good conductors of heat and electricity; they do not as a rule combine with hydrogen, producing non-volatile compounds. Their oxygen compounds generally have the character of basic anhydrides, i.e., they form bases with water (p. 99, *b*). Many metals are soluble in water when in a finely divided state (p. 54), while no metal is soluble in other solvents without undergoing a change. The compounds of the metals with the non-metals are decomposed by the electric current, the metal separating out at the negative pole.

The *non-metals* or *metalloids* are (with the exception of hydrogen) poor conductors of heat and electricity or are non-conductors, and all combine with hydrogen, forming volatile generally gaseous compounds. Most of the oxygen compounds of the non-metals have the character of acidic anhydrides, i.e., they form acids with water (p. 98, *a*). Most of the non-metals are soluble without change in most solvents. Their compounds with metals are always decomposed by the electric current, so that the non-metal separates at the positive pole.

A sharply defined division of the elements into metals and non-metals is not possible because often bodies are separated which have great similarity in all their chemical properties. Thus gaseous hydrogen is closely related in its chemical behavior to the metals, while arsenic and antimony have a metallic appearance, but behave chemically like the metalloids; also various elements like carbon and phosphorus are known in the metalli as well as the non-metallic condition. It is therefore indispensab

npounds of the same elements are known,
ound having the element with highest valence
atin root of the metal, while the one having
alence terminates in *ous*. Thus:

$\overset{I}{Hg_2O}$,	$\overset{II}{HgO}$,	$\overset{I}{Hg_2S}$,	$\overset{II}{HgS}$,
Mercurous oxide.	Mercuric oxide.	Mercurous sulphide.	Mercuric sulphide.

to be indicated by the prefixes *proto* and *per*.

$IgCl_2$,	$FeCl_2$,	$FeCl_3$,
rcury hloride.	Iron protochloride.	Iron perchloride.

npounds are known of the same elements,
en, chlorine, bromine, etc., atoms contained
ted by the Greek prefixes. For example:

P_2O_3,	P_2O_4,	P_2O_5,
Phosphorus trioxide.	Phosphorus tetroxide.	Phosphorus pentoxide.

have the prefix *sesqui* to differentiate them
s CrO_3. The different steps in oxidation are
s: *suboxide*, *oxide*, *sesquioxide* and *super-* or
ead suboxide; PbO, lead oxide; Pb_2O_3, lead
superoxide (also lead peroxide).

ary and Higher Compounds.

compounds belonging to this group are the
which have the property in common of being
already been discussed from the standpoint of
4.

A. Acids.

s of hydrogen with non-metals and also with
rogen being entirely or partly replaceable by
contact with a metal or a metallic hydroxide
lic oxide (a basic anhydride), producing com-
led salts. Thus:

$\overset{II}{Zn}$	=	$ZnCl_2$	+	2H
Zinc.		Zinc chloride.		Hydrogen.

Acids, when soluble in water,
(p. 84). According to composition we differenti
free acids and those which contain oxygen (oxy
called mono-, di-, tri-, etc., basic (mono-, di-,
mono-, di-, tri-, etc., hydric) acids according to w
one, two, three, etc., atoms of hydrogen replaceal

Acid anhydrides, acidic oxides (also incorrec
acids), are those oxides produced by removing a
the corresponding quantity of oxygen, in the forr
or more molecules of an oxyacid; for example:

$H_2SO_4 = SO_3 + H_2O$ $2H_3PO_4 =$ I
Sulphuric acid. Sulphuric anhydride. Phosphoric acid. Pho anh

In the same manner the *sulphoacids* yield anl
ing H_2S; thus, $2H_3AsS_3 = As_2S_3 + 3H_2S$.

The acid anhydrides do not have any acid
with water, forming acids again.

Acid radicals are the groups obtained on the
groups OH from a molecule of oxyacids (ofte
for example:

SO_2 acid radical of sulphuric acid SO
NO_2 " " " nitric " N
PO " " " phosphoric " P

Oxygen free acids are designated by addin
the element or group forming the acid, this ele

O_3, chloric acid; HCNO, cyanic acid; H_2SO_4, sul-
AsO_4, arsenic acid; H_4SiO_4, silicic acid.
of the same elements are known we designate the one
gen with the termination *ous;* thus, H_2SO_3, sulphurous
ies of acids of the same elements are known, the one
ygen has the prefix *hypo* (below), while the richest in
he prefix *hyper* (above) or *per;* thus:

Hypochlorous acid.
Chlorous acid.

$HClO_3$, Chloric acid.
$HClO_4$, Hyper or Perchloric acid.

d HCl_2O_5 was known it would stand between chlorous acid
acid and would be called hypochloric acid.
cids of nitrogen are called: hyponitrous acid, HNO; nitrous
nitric acid, HNO_3.

B. Bases.

re compounds of hydroxyl groups HO^- with metals,
ming in contact with an acid replace its hydrogen entirely
the metal contained in it, producing compounds of the
d salts; for example:

$$\underset{\text{Sodium ydroxide.}}{\overset{\text{I}}{\text{Na}}\text{OH}} + \underset{\text{Nitric acid.}}{\text{HNO}_3} = \underset{\text{Sodium nitrate.}}{\overset{\text{I}}{\text{Na}}\text{NO}_3} + \underset{\text{Water.}}{\text{HOH}}$$

luble in water the bases have a caustic taste and have an
ction (basic, p. 84). According as the bases contain one,
etc., hydroxyl groups they are called mono-, di-, tri-, etc.,
o-, di-, tri-, etc., valent or mono-, di-, tri-, hydric bases).
nhydrides are those oxides which are produced when all
gen combined with the corresponding quantity of oxygen
removed from one or more molecules of a base; for example:
$_2O+H_2O$; $Zn(OH)_2 = ZnO+H_2O$; $2Fe(OH)_3 = Fe_2O_3+3H_2O$.
ame given to the base is obtained by adding the word *hy-*
the name of the element forming the base. If an element
eral hydroxides then the designation is the same as the
ding oxides (p. 97); for example: $Fe(OH)_2$, ferrous hydrox-
$H)_3$, ferric hydroxide.

C. Salts.

re the compounds produced by completely or partly replac-
ydrogen of an acid by a metal. This can take place as fol-

635768

a double decomposition takes place with the formation of w

$$KOH + HCl = KCl + HOH;$$
$$Ca(OH)_2 + H_2SO_4 = CaSO_4 + 2HOH;$$
$$CaO + H_2SO_4 = CaSO_4 + HOH.$$

By an acid anhydride combining directly with a basic a
thus, $Fe_2O_3 + 3SO_2 = Fe_2(SO_4)_3$.

Normal or *neutral salts* are those which are obtained
of the replaceable hydrogen in an acid is replaced by a me
of them have a neutral reaction (p. 85); still, many normal
indeed acid salts have an alkaline reaction when they a
from weak acids; on the other hand many normal salt
when they are derived from weak bases (see p. 86).

In giving names to the oxysalts all the salts containing
salt-forming element are given a generic name by rep
last syllable of the Latin name of the acid-forming elem
suffix *ate* for those richest in oxygen and the suffix *ite* fo
gous compound poorer in oxygen.

For example:

$MClO$	Hypochlorite
$MClO_2$	Chlorite
$MClO_3$	Chlorate
$MClO_4$	Perchlorate

The special name is formed by placing the name of the met
the hydrogen before the generic name. For example:

$KClO$	Potassium hypochlorite
$NaClO_2$	Sodium chlorite
$NaClO_3$	Sodium chlorate
$AgClO_4$	Silver perchlorate

The special names of two salts which contain the s

I. NON-METALS OR METALLOIDS.

rding to the periodic system the elements belonging to this re classified as follows:

en,	Oxygen,	Nitrogen,	Helium,	Carbon,
e,	Sulphur,	Phosphorus,	Argon,	Silicon,
,	Selenium,	Arsenic,	Neon,	Germanium,
e,	Tellurium.	Antimony,	Krypton,	Tin,
	———	Bismuth,	Xenon.	Lead.
	———	Boron.	———	———
t.	Bivalent.	Trivalent.		Quadrivalent.

elements bismuth, germanium, tin, and lead, which have ed metallic properties, will be treated of in connection with ls.

gen hardly belongs to either of the above groups, as it has alloid and metallic characteristics, and forms at the same type of all elements.

Hydrogen.

Atomic weight 1.01 = H.

nce. Free in small quantities in gases of volcanoes and roleum wells, enclosed in the potassium salts of Stass- rock salt of Wieliczka, and in the meteoric iron of Lenarto. mposition of organic substances hydrogen is set free; urs in the intestinal gases of man and certain animals s in the atmosphere. The chief quantity of hydrogen nbination with oxygen as water; all plants and animals bined hydrogen as a chief constituent. As shown by ysis free hydrogen exists in large quantities in the fixed he gases surrounding the incandescent solar nucleus.

vols. hydrogen are evolved at the nega-

many compounds rich in oxygen, i.e.,
decomposes into mercury and oxygen:
ioxide (MnO_2), which is converted into
gives off oxygen, $3MnO_2 = Mn_3O_4 + 2O$;
hich decomposes into barium monoxide
).

ances rich in oxygen, such as manganese
ssium persulphate, potassium dichromate
cid, or by heating a solution of chloride
copper oxide (see these).
the cold by the action of water upon a
potassium ferricyanide or by the action
ides or percarbonates; of hydrochloric
ioxide and manganese dioxide; of chloride
anate upon hydrogen peroxide, etc. (see

. On heating barium monoxide (BaO)
rrent of air it is converted into barium
temperature decomposes into barium
the pressure is diminished. On in-
assing air through we again obtain
nposes as above stated (p. 72). (Brin

heating calcium plumbate (Ca_2PbO_4) in
$PbO_4 + 2CO_2 = 2CaCO_3 + Pb + O_2$. On heat-
ir calcium plumbate is re-formed (Kassner's

ing the pressure on liquefied air (p. 41)
place; the liquefied nitrogen evaporating
oxygen on account of its lower boiling-
consists of about 80 per cent. oxygen.

orless, and tasteless gas, slightly soluble
r than air, liquefiable at −182° to a light
1.12 (p. 41) and which solidifies at −252°

weighs 1.429 g. at 0° and 760 mm.; hence
to air is $\frac{1.429}{1.293} = 1.105$.

xygen = 16 serves as a basis for the deter-
ht of the other elements, and the molecular

bine with the oxygen thereof (combustion
lace very slowly, then the total development
apid oxidation; still the temperature cannot
light. Often the heat cannot be determined
heat by radiation and conduction.

w oxidation of organic bodies which takes
n of lower organisms. As the final pro-
s process as in the combustion of organic
er this process as a slow combustion.
ow process of combustion when the oxygen
bines with a part of the carbon of the tissues,
which is expired, while the other oxidation
by the urine, etc. The body temperature
tion.

up from the atmosphere the carbon dioxide
animals, combustion, decay, etc., by means
es, and decompose this under the influence of
serves to build up its tissues, and into oxygen,
plants therefore perform a reduction process
he animal body.

nical sense, is any chemical process accom-
of light. As the burning of a body depends
therefore oxygen cannot burn in the air, as
there with which it can combine. Oxygen,
hydrogen, ammonia, sulphur vapors, etc.,
these bodies with the development of heat
y temperature, ignition temperature (see
mence the combination.

mbine directly with oxygen, it does not burn
t in the air. Oxygen, on the contrary, does
nd burns therein for the same reason that
; coal-gas burns in the air, hence the air (its
l-gas. It follows from this, therefore, that
ty of bodies are only relative phenomena.

lly continues to burn because of the heat set
the particles acting upon each other, heating
nition temperature.

y introducing a cold metal in a small flame)
uished. If a wire gauze is held over a tube

porate, the oxygen goes off at −182°, while the
−120° remains as a deep-blue liquid.
less, in deep layers a bluish gas having a peculiar
rine, when not too dilute causing an irritation
ranes, liquefiable at −120°, forming a deep-blue
explodes as it is suddenly transformed in oxygen
nent of heat. It is readily soluble in ethereal and
ghtly soluble in water. In the solution of ozone in
converted into oxygen and hydrogen peroxide:
. Although oxygen generally combines with
it higher temperatures, ozone has an oxidizing
ary temperatures (especially when moist). Bright
by ozone into black silver peroxide, white lead
wn lead peroxide, black lead sulphide (PbS) into
($PbSO_4$), etc. It destroys all vegetable pigments
n bleaching) and oxidizes all organic substances;
must not be used in its preparation.
sed through a glass tube heated above 400°, it is
oxygen gas, when the volume increases one-half;
y of ozone is one-half greater than that of oxygen,
of 16. Hence the molecular weight of ozone is
follows that a molecule of ozone contains 3 atoms
2 volumes of ozone yield 3 volumes of oxygen.

on of ozone a considerable addition of energy takes
heat, electricity, etc. This explains the great chemical
ns on oxidation with ozone 32.4 more calories are
n oxygen (p. 69). As an endothermic compound
e suddenly converted into oxygen gas with explosive

Paper moistened with potassium iodide solution
turns faintly or deep blue, depending upon the

e is not changed by oxygen, but by ozone, on the
sium is oxidized and the iodine set free: O_3+2KI+
I_2. Free iodine can be detected by its property
leep blue.

m guaiacum turns blue with ozone.
ide also gives the reaction with potassium iodide

for projections, etc. (Drummond
ssed over heated metallic oxides, copper
(Fe_2O_3), these are reduced into metals with
$CuO+2H=Cu+H_2O$. $Fe_2O_3+6H=2Fe+$
le is weighed before and after the experiment,
lso weighed, then the loss in weight of the
the quantity of oxygen present in the water

e apparent contradiction that H yields H_2O
iron with water yields H see p. 61.

er to prepare chemically pure water (*aqua*
e, ordinary water is distilled, i.e., we convert
a retort by boiling and condensing this vapor
(p. 50). In this procedure all dissolved salts,
t, as they are not volatilized with the vapor
lved gases (air, carbon dioxide, and ammonia)
pass off with the vapor produced; hence the
tillate must be discarded.

ater is a tasteless and odorless fluid, colorless
ouncedly blue in layers of six to eight meters;
ole, a poor conductor of heat and electricity.
n, i.e., it has neither acid nor alkaline proper-
ith basic oxides, and acids with acidic oxides

aline-earth metals decompose water even at
. The other metals (with the exception of
mercury, silver, platinum, and gold), as well
, only decompose water at higher temperatures
hydrogen (p. 104).

e unit for the determination of specific gravi-
bodies, as well as the determination of specific
t possesses the greatest specific heat, with the
(p. 22).

ent is passed through acidulated water, twice
set free at the negative pole as oxygen at the

0° (ice formation) and expands at the same

1). Even at ordinary temperatures water
This conversion into vapor must necessarily
sorption of heat; hence the lower temperature
ls upon the evaporation of the sea-water. On
ation of water, the gases generated from watery
noist (p. 40). Vapor of water is colorless and
ume of water at 100° yields 1696 volumes of
liter of vapor of water weighs at 100° and
gram. In the passage of water at 100° into
the passage of ice into water at 0°, a consid-
t is absorbed and set free again on the con-
n.

water at 100° warms on conversion into water
ter from 0 to 100° or one kilo 536°. The heat
er, therefore, amounts to 536 heat-units. Sat-
follow the law of gases (p. 15). Their vapor
uch greater degree than their temperature; i.e.,
) of saturated vapor of water at

100° is 760 mm.
120.6° " 2 atmospheres.
180.3° " 10 "
365.0° " 194.6 "

not be made liquid by any pressure; 365° is
194.6 atmospheres the critical pressure of

is that water contained in many crystalline
d, which stands in certain relationship to

hich a salt at equal temperature takes up
ays the same; at different temperatures
ent quantities of water and then also has
thus when magnesium sulphate crystallizes
al crystals, $MgSO_4+4H_2O$, between 7° and
$_4+5H_2O$, below 6° monoclinic crystals,

water of hydration, is that portion of
which is firmly united and which, when
ter change in the properties of the sub-
than the water of crystallization (see

ge which many crystals undergo when
they lose water of crystallization; they

ling; these contain especially considerable free carbon
xide; the alkaline ones besides this sodium carbonate; the
ine, sodium chloride; the alkaline-saline, carbon dioxide
d sodium sulphate or common salt.
tter water contains considerable magnesium salts.
lphur-water contains sulphuretted hydrogen.
alt water contains common salt, also bromine and iodine salts.
Chalybeate water contains iron salts.
a-water differs from all other waters by its containing large
of common salt, which amounts on an average to 2.7 per cent.,
contains bromine, iodine, calcium, magnesium compounds, etc.,
the quantity of solid bodies is about 3.5 per cent.

Potable water. For this purpose not only is spring-water
but also water from rivers and lakes. Such waters are purified
impurities and insoluble substances by filtration by passing it
ugh a receptacle which contains above sand, then gravel, then small
nes and, below, larger stones. In order to purify potable waters for
usehold use, various filters of carbon or spongy iron are used whereby
he water becomes clearer and of a better taste; still the injurious bodies
cannot be wholly eliminated by any process of filtration. Good drinking-water must be clear, colorless, and odorless, must have a fresh taste (due to the carbon dioxide), must not contain any ammonia, no nitrous acid, and only small quantities of chlorine, nitrates, or sulphates, organic substances, and must not be too hard; the evaporated residue must not show under the microscope any fungi, infusoria, etc. A drinking-water must not necessarily be discarded because it contains the above compounds, but because their presence may possibly indicate a contamination with animal decomposition products which are not directly detectable.

Hydrogen Peroxide, H_2O_2 or H-O-O-H. *Occurrence.* In very small amounts in the air, in rain and snow; it is formed to a slight extent in the evaporation of oil of turpentine (occurrence in the air of pine forests) and other ethereal oils, and in the slow oxidation (action in grass-bleaching) and combustion in the presence of water as well as in the electrolysis of water.

Preparation. 1. On passing carbon dioxide into water holding barium dioxide (BaO_2) in suspension, or this latter added to dilute cold sulphuric acid (p. 110):

$$BaO_2 + H_2O + CO_2 = BaCO_3 + H_2O_2;$$
$$BaO_2 + H_2SO_4 = BaSO_4 + H_2O_2.$$

The insoluble barium carbonate or barium sulphate which precipitates is filtered off; the obtained dilute solution may be concentrated by evaporation not over 70° until it contains 45 per cent. H_2O_2, this solution is then shaken with ether which dissolves the H_2O_2, and this latter solution on distillation yields H_2O_2, which is further concentrated in a vacuum.

mpounds with Hydrogen.

de, H_2S. Hydrogen Persulphide, H_2S_x

, Sulphuretted Hydrogen, H_2S. *Occurrence.*
he gases of volcanoes and in sulphur-waters;
es containing sulphur undergo putrefaction, as
of the intestine of carnivorous animals and in

y the action of nascent H upon sulphur diox-
$O+H_2S$.
ulphur and many metallic sulphides in a current
$+2H=2Ag+H_2S$.
By the action of dilute hydrochloric or sulphuric
sulphides, especially ferrous or antimony sulphide:

$$FeS+H_2SO_4=FeSO_4+H_2S;$$
$$Sb_2S_3+6HCl=2SbCl_3+3H_2S.$$

Colorless, poisonous, gas having a disagreeable odor
ten eggs (which contain the same), having a specific
S; inflames and burns with a blue flame into sulphur
water: $H_2S+3O=H_2O+SO_2$; if the supply of oxygen
, then sulphur is set free: $2H_2S+4O=2H_2O+SO_2+S$.
e liquefied at −74°, forming a colorless liquid which
crystals at −85°. One volume of water at 0° dissolves
s of the gas; this solution reddens litmus, and is oxidized
with the setting free of sulphur by many compounds con-
ygen, such as chromic acid, nitric acid, etc., as well as by
en of the air: $H_2S+O=H_2O+S$.
ger oxidizing agents, such as fuming nitric acid, lead peroxide,
ite the gas, and when mixed with oxygen it explodes when a
applied. Sulphuretted hydrogen is, therefore, a powerful
g agent. Chlorine, bromine, and iodine decompose it with the
free of sulphur, they combining with the hydrogen: $H_2S+2Cl=$
$+S$. Sulphur dioxide acts in a similar manner: $SO_2+2H_2S=$
$+3S$.
lost metals decompose sulphuretted hydrogen on heating them
her with the formation of sulphides (p. 120), and hydrogen is set
ume. The metallic oxides have a similar action and

With certain of these bodies the
in the cold; hence silver, copper, w
in the air, as this often contains s
hydrogen: $2Ag+H_2S=Ag_2S+2H$.
ted hydrogen behaves like the
the chlorine group, and the sulphide
hydrosulphuric acid.

sulphides, such as NaHS, have a n
the HS' ion is only slightly
of the H' ions is not sensible, w
have an alkaline reaction
by hydrolytic dissociati
+OH'.

of its behavior to metals
its aqueous solution, is a
the metals:
obtained with H_2S
which are not acted
which are insoluble

which are soluble i
of this behavior sulp
analysis in separating th
sulphuretted hydrogen in
which has previously
the first group precipit
by filtration and the f
group precipitate,

sulphides have a chara
separating the metals
of identification fo
it precipitates
arsenic sulph
solutions f
ferrous s
ferrous, a
hydrogen onl

1. Sul
with
is black
when

e, H_2S_2 or HS–SH, is obtained when a watery e, for instance, of calcium disulphide (CaS_2), to an excess of dilute hydrochloric acid: S_2 (p. 121). It forms a thick, yellow liquid dor, which bleaches organic pigments, and nposes, but quicker on heating, into H_2S+S. probably has the formula H_2S_5, which body the unstable hydrogen polysulphide produced: $4H_2S_2=H_2S_5+3H_2S$; $4H_2S_3=2H_2S_5+2H_2S$.

b. Compounds with Oxygen.

	Hyposulphurous acid,	$H_2S_2O_4$.
, SO_2.	**Sulphurous acid,**	H_2SO_3.
	Pyrosulphurous acid,	$H_2S_2O_5$.
e, SO_3.	**Sulphuric acid,**	H_2SO_4.
	Pyrosulphuric acid,	$H_2S_2O_7$.
xide, S_2O_3	—	
ide, S_2O_7	**Persulphuric acid,**	$H_2S_2O_8$.
	Oxysulphuric acid,	H_2SO_5.
	Thiosulphuric acid,	$H_2S_2O_3$.
	Dithionic acid,	$H_2S_2O_6$.
	Trithionic acid,	$H_2S_3O_6$.
	Tetrathionic acid,	$H_2S_4O_6$.
	Pentathionic acid,	$H_2S_5O_6$.

only sulphuric acid and pyrosulphuric acid can be acids are only known in aqueous solution or as salts. ds the anhydrides are not known. The last four up of acids called polythionic acids (πολύς, many, ulphuric acid, pyro- and oxysulphuric acids, as well recipitated by barium salt solutions from their acid

de, Sulphurous Anhydride, SO_2. *Occurrence.* In noes.

. On a large scale by burning sulphur or by or from the residue from the Leblanc soda manu-

y heating copper, carbon, or sulphur with con- c acid:

$H_2SO_4+C\ =2H_2O+CO_2+2SO_2$;
$H_2SO_4+Cu=2H_2O+CuSO_4+SO_2$;
$H_2SO_4+S\ =2H_2O+2SO_2$.

quantities by the action of sulphuric acid u
or upon sodium bisulphite:

$aSO_3+H_2SO_4=CaSO_4+H_2O+SO_2;$
$HSO_3+H_2SO_4=Na_2SO_4+2H_2O+2SO_2.$

g sulphur with metallic oxides:

$S=2CuS+SO_2;$ $MnO_2+2S=MnS+SO_2.$

Colorless, irritating, neutral gas, 2.21 times heavier
able at −10° (p. 41) to a colorless liquid which solidifies
at −76°. It is not combustible and does not support
n of carbon compounds, but many metallic oxides
heated in it with the production of flame; thus brown
s converted into white lead sulphate:

$$PbO_2+SO_2=PbSO_4.$$

es many organic pigments in the presence of water; this
pend upon oxidation like the chlorine bleaching, but
on the union of the sulphurous acid, H_2SO_3, produced
gments. These compounds are unstable and on warming
es and acids, etc., decompose under certain circumstances
color appears again (use of burning sulphur for bleaching;
res are not decolorized so completely with chlorine as with
has rather great affinity for oxygen, hence it removes the
m many oxygen compounds, such as chromic acid, iodic
e below), etc. It is, therefore, a powerful reducing agent; it
nites directly with free oxygen in the presence of spongy
m, etc. (p. 126); it is converted into sulphuric acid by the
ns when in watery solution: $SO_2+2H_2O+2I=H_2SO_4+2HI.$
therefore, employed to remove the excess of chlorine used
aching certain materials which would otherwise destroy the
On the other hand, strong reducing agents (H, H_2S)
it again to sulphur (p. 122). It prevents putrefaction
rmentation and serves as a preservative (sulphuring of wine-
, etc.). Water dissolves 50 times its volume of this gas

ction. If a piece of paper moistened with starch and iodic and which form the commercial product. They fume strongly in ir, as they are somewhat volatile even at ordinary temperatures, the vapor absorbs water from the air, forming sulphuric acid, h immediately condenses into small visible globules. It dises in water with a hissing sound with the production of great , forming sulphuric acid: $SO_3+H_2O=H_2SO_4$.

Sulphuric Acid, Oil of Vitriol, H_2SO_4 or $HO-SO_2-OH$. *Occure.* Free to very trivial extent in certain volcanic springs America, and in the air in regions where large quantities of coal burnt. It occurs in large quantities combined as sulphates, of ich calcium sulphate, $CaSO_4$, gypsum, forms entire geological ata, also as barium sulphate, $BaSO_4$, and strontium sulphate, O_4. Animals and plant fluids also contain sulphates, generally the alkali metals.

Preparation. 1. In small quantities by boiling sulphur with ncentrated nitric acid: $S+2HNO_3=H_2SO_4+2NO$.

2. By dissolving sulphur trioxide prepared by the contact method water. On account of the ready and less dangerous transportaon of SO_3 it is economical to prepare sulphuric acid by dissolving O_3 in water at the locality where it is to be used. For these reasons e following method of preparation is used to a less extent at the esent day.

3. By the oxidation of sulphur dioxide by nitric acid or its decomosition products in the presence of water and air in chambers lined ith lead plates (lead chambers). An aqueous solution of sulphur oxide is only slowly oxidized into sulphuric acid by the oxygen of air (p. 126); but this may be made to take place more quickly the presence of contact substances or when compounds which dily give off oxygen are present; such compounds are nitric acid O_3) and nitrogen dioxide (NO_2), which are reduced to nitric oxide) thereby.

he sulphur dioxide is prepared by roasting the residues from the ane soda manufacture, the iron residues used in the purification uminating-gas (see Potassium Ferrocyanide), or by roasting metallic ides and especially iron pyrites (FeS_2), copper pyrites ($CuS+FeS$), pyrites (PbS), zinc blende (ZnS), which are converted into oxides

$2FeS_2+11O=Fe_2O_3+4SO_2$.

e nitric acid is generated from $2NaNO_3+H_2SO_4$ by introducing ixture into crucibles placed in the roasting-ovens and the vapors in crude sulphuric acid. It used to be obtained by heating roasted ferrous sulphate.

On roasting ferrous sulphate it is transformed into ferric oxide and ferric sulphate, $6FeSO_4+3O=2Fe_2(SO_4)_3+Fe_2O_3$, which decomposes at a red heat according to the following equation: $Fe_2(SO_4)_3=Fe_2O_3+3SO_3$; the sulphur trioxide which distils off is collected in small quantities of water or sulphuric acid; the iron oxide (Fe_2O_3) which remains in the retort is called colcothar.

It forms a thick liquid which fumes in the air and has a specific gravity of 1.85 to 1.90 and may be considered as a compound of sulphuric anhydride with sulphuric acid as on cooling the following acid separates:

Pyro- or *disulphuric acid*, $H_2S_2O_7$, forms colorless crystals which melt at 35° and is prepared commercially by dissolving SO_3 into concentrated sulphuric acid. On heating it decomposes into H_2SO_4 and SO_3 (p. 126); its salts are obtained by heating the primary sulphates: $2KHSO_4=H_2O+K_2S_2O_7$, which further decomposes on heating into $K_2SO_4+SO_3$.

Sulphates are obtained either by dissolving the respective metals in sulphuric acid or by neutralizing a base with sulphuric acid, also by oxidizing the metallic sulphides or metallic sulphites at a gentle heat in the air. In this wise copper and iron sulphates are prepared on a large scale: $CuS+4O=CuSO_4$.

The sulphates of the alkalies, of the alkaline earths, and of lead are not changed on heating to a high degree; the other sulphates dcompose into sulphur dioxide or sulphur trioxide and metal (o metallic oxides) and oxygen.

Detection. Sulphuric acid and the soluble sulphates give whi precipitates of barium sulphate ($BaSO_4$) or lead sulphate (PbS with barium or lead salt solutions. These precipitates are insolu in acids.

On fusion with sodium carbonate the insoluble sulphates converted into soluble sodium sulphate in which the sulphuric can be detected as above described.

Sulphur sesquioxide, S_2O_3, is produced by introducing po sulphur into sulphur trioxide, and forms bluish-green crystals: S S_2O_3; with water it decomposes into H_2SO_4+S.

Hyposulphurous acid, $H_2S_2O_4$, is obtained as a zinc sal action of zinc upon aqueous sulphurous acid: $Zn+2H_2SO_3=$ $2H_2O$; it is, like its salts, only known in aqueous solution, which readily decomposes, and is a strong reducing and bleaching

metals. Phosphorus, thin sh
powdered arsenic, antimony, boron, sili
chlorine gas even at ordinary temperatures
Chlorine has very strong affinities for hyd
volumes of chlorine and hydrogen comb
daylight, while in sunlight it immedia
hydrochloric acid. A hydrogen flame bu
vice versa (p. 109). Many organic co
carbon and hydrogen lose their hydrogen
hydrochloric acid; thus paper moistened
pound of carbon with hydrogen) when i
inflames, and carbon is set free. Chlorine
the air, but supports the combustion of a
gas (a mixture of hydrocarbons) with the
(soot). This phenomenon may be explaine
hydrogen of the respective compound with
free of heat, which heats the gas to a red
present separates out.

Chlorine destroys all natural and many ar
as it combines with the same or oxidizes them
water it unites with the hydrogen of the bo
oxygen: $H_2O+2Cl=2HCl+O$. Its disinfec
destruction of infectious and odoriferous
also depends upon this fact. (Use of chlo
water for bleaching and disinfecti

a. Compounds with Hydrogen.

oride, Hydrochloric Acid, HCl. *Occurrence.* Free
canoes, and to a slight extent in gastric juice.
A mixture of equal volumes of hydrogen and
ept unchanged in the dark; in diffused daylight they
n direct sunlight they combine immediately with ex-
forming hydrochloric acid. The volume of the gas
ed.

$$\left\{\begin{matrix}H\\H\end{matrix}\right. + \left\{\begin{matrix}Cl\\Cl\end{matrix}\right. = \left\{\begin{matrix}H\\Cl\end{matrix}\right. + \left\{\begin{matrix}H\\Cl\end{matrix}\right.$$

ction of chlorine upon water and many organic

1. From crude hydrochloric acid (see below) by

ared on a large scale in the Leblanc soda manu-
ng sodium chloride with sulphuric acid:

$$\underset{\text{dium oride.}}{NaCl} + \underset{\text{Sulphuric acid.}}{H_2SO_4} = \underset{\text{Sodium sulphate.}}{Na_2SO_4} + \underset{\text{Hydrochloric acid.}}{2HCl.}$$

sulphate obtained as a by-product is used in the
glass or is converted into sodium sulphide, Na_2S,
the manufacture of cellulose.
e scale by passing superheated steam over magnesium
), which is obtained as a by-product in many chemical

$$2MgCl_2 + H_2O = MgO.MgCl_2 + 2HCl.$$

Colorless, irritating gas which is non-combustible
oes not support combustion. It is 1.25 times heavier
es in the air (because it abstracts water therefrom and
lrochloric acid, which separates as a vapor), liquefiable
rming a colorless liquid which solidifies at −116°.
ume of water dissolves 450 volumes of this gas at 15°
herewith a fuming, colorless, strongly acid liquid having
ravity of 1.21, which contains 43 per cent. by weight of

b. Compounds with Oxygen.

Chlorine monoxide,	Cl_2O.	**Hypochlorous acid,**	$HClO$.
Chlorine dioxide,	ClO_2.	—	
(Chlorine trioxide,	Cl_2O_3.)	**(Chlorous acid,**	$HClO_2$.)
Chlorine tetroxide,	Cl_2O_4.	—	
(Chlorine pentoxide,	Cl_2O_5)	**Chloric acid,**	$HClO_3$.
Chlorine heptoxide,	Cl_2O_7.	**Perchloric acid,**	$HClO_4$.

Chlorine trioxide and chlorine pentoxide are only known mixed as chlorine tetroxide; chlorous acid is only known in the form of its salts, the chlorites (p. 138).

Chlorine Monoxide, Cl_2O. *Preparation* Cooled chlorine gas is passed over mercury oxide (HgO) and the vapors produced condensed in a cooling mixture: $HgO+4Cl=HgCl_2+Cl_2O$

Properties. It forms a red liquid which boils at +5° and then forms a yellowish-red, poisonous, strongly oxidizing gas with a disagreeable odor. It soon decomposes into its constituents, which can be brought about especially by shock, heating, or in contact with oxidizing substances, often with an explosion.

Hypochlorous Acid, $HClO$. *Preparation.* Chlorine monoxide is very soluble in water, forming hypochlorous acid: $Cl_2O+H_2O=2HClO$; on concentration this splits into chlorine monoxide again, so that anhydrous $HClO$ is not known.

Properties. The dilute, nearly colorless solution may be distilled without decomposition; the concentrated yellow solution decomposes on heating and in the sunlight with the formation of chloric acid and chlorine: $3HClO=2HCl+HClO_3$; $2HClO+2HCl=4Cl+2H_2O$. With hydrochloric acid it evolves all the chlorine of both compounds: $HClO+HCl=H_2O+Cl_2$ It is a very weak acid, which does not decompose carbonates, but is a very strong oxidizing agent.

Hypochlorites are also readily decomposable and strong oxidizing agents. They are prepared by saturating $HClO$ with the respective bases. Commercially they are obtained, mixed with chlorides, by passing chlorine (generally electrolytically prepared) into cold and dilute solutions of the strong bases:

$$\underset{\substack{\text{Sodium}\\\text{hydroxide}}}{2NaOH}+2Cl=\underset{\substack{\text{Sodium}\\\text{hypochlorite.}}}{NaClO}+\underset{\substack{\text{Sodium}\\\text{chloride}}}{NaCl}+H_2O.$$

Nitric acid sets hypochlorous acid free from the hypochlorites, and this can be separated by distillation: $NaClO+HNO_3=NaNO_3+HClO$. Hydrochloric acid sets chlorine free, and certain metallic oxides generate oxygen from hypochlorites (see Chloride of Lime).

Chlorine Dioxide, ClO_2, or Chlorine Tetroxide, Cl_2O_4 (formerly called Hypochloric Acid). *Preparation.* Small quantities of potassium chlorate ($KClO_3$) are gradually and carefully added to concentrated sulphuric acid and then distilled at a temperature not above

On the distillation of bromides with concentrated sulphuric acid e also obtain hydrobromic acid, but this in part is immediately ecomposed so that also free bromine and sulphur dioxide are produced: $2HBr + H_2SO_4 = 2H_2O + 2Br + SO_2$.

3. If phosphorus bromide is warmed with water, or if we allow bromine to flow into amorphous phosphorus under water, we obtain hydrobromic acid:

$$\underset{\text{Phosphorus bromide.}}{PBr_3} + 3H_2O = 3HBr + \underset{\text{Phosphorous acid.}}{H_3PO_3}.$$

4. By passing H_2S into water containing bromine and expelling the excess of H_2S by careful warming, we obtain an aqueous solution of hydrobromic acid: $H_2S + 2Br = 2HBr + S$.

Hydrobromic acid may also be obtained by the action of Br upon organic hydrogen compounds such as naphthalene, $C_{10}H_8$.

Bromides are obtained in a manner analogous to the chlorides (see also Potassium Bromide).

Properties. Colorless gas, irritating odor, fumes in the air, partly decomposes at 800°, liquefiable at −73° and solidifying at −120°, and very readily soluble in water. Its watery solution boils at 125° (p. 53) and then contains 48 per cent. HBr and has a specific gravity of 1.49. This solution turns red in the air, due to the separation of bromine: $2HBr + O = H_2O + 2Br$.

Detection. 1. Silver nitrate precipitates yellowish-white silver bromide, AgBr, from solutions of HBr or of bromides. This precipiate is insoluble in nitric acid, but soluble in considerable ammonia, nd darkens in the light.

2. If a solution of HBr or a bromide is treated with chlorineater, the bromine is set free, which, when shaken with carbon sulphide, gives a reddish-brown color thereto.

b. Compounds with Oxygen.

Hypobromous acid,	$HBrO$.
Bromic acid,	$HBrO_3$.
Perbromic acid,	$HBrO_4$.

At the present time we do not know of any oxide of bromine, but only above-mentioned oxyacids, and these indeed only in watery solu- i. They are prepared in the same manner as the corresponding rine compounds.

moist an alkaline reaction
cted in the smallest quantity;
must be collected over mercury,
olves 1148 volumes (=0.875 parts by
739 volumes (=0.526 parts by weight).
to a colorless liquid, which solidifies at −75°.
ls at −34° and absorbs considerable heat on
made use of in the production of artificial ice and
efied at 10° by a pressure of 7 atmospheres.
g very great activity, as it has powerful action
ls and metals, on the latter especially in the
water. On passing dry ammonia over heated
nitride is produced: $3K+NH_3=NK_3+3H$;
n, magnesium nitride is obtained: $3Mg+2NH_3=$
t burn in the air, but it burns, on the contrary,
a yellowish flame, forming water and nitrogen;
made to burn in ammonia (p. 109): $2NH_3+3O=$
mes in ammonia gas with the formation of white
m chloride (p. 146).
h oxygen and passed over heated spongy platinum
nitric acid: $NH_3+4O=HNO_3+H_2O$.
r hypobromites, for instance solutions of chloride
hypobromite, decompose ammonia, setting free all
47).

nia is the name given to the watery solution of
specific gravity is less according to the amount of
ains. It has the odor of ammonia and an alkaline
cipitates the heavy metals as hydroxides from their
$+2NH_3+2H_2O=Fe(OH)_2+(NH_4)_2SO_4$. It behaves,
rong base and may be considered as a watery solution
responding to K−OH). This compound is indeed
but organic derivatives of the same, the so-called
(see Part III), which behave like aqueous solutions
OH or NaOH. Caustic ammonia having a specific
tains 10 per cent. by weight, and is ordinarily ob-
ng the commercial caustic ammonia with water.

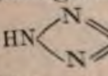
combustible, readily soluble in water, having a strong
nd is a weak base. With the aldehydes it forms oximes

e *salts* are produced by the direct union of a hydroxyl-
ith one hydrogen of the acid. Hydroxylamine chloride,
ms colorless, poisonous crystals, which are readily soluble
reducing action but not explosive.

)iamid, H_2N-NH_2. *Preparation.* By the action of
upon potassium nitrite (KNO_2) we obtain nitric oxide-
ite, $K_2SO_3 \cdot N_2O_2$, which yields hydrazine when treated
lution with nascent hydrogen (sodium amalgam):
$=N_2H_4+K_2SO_4+H_2O$. On fractional distillation of
btain hydrazine hydrate, $N_2H_4 \cdot H_2O$, which yields anhy-
by distilling in a vacuum with barium oxide.

Caustic, basic liquid having a peculiar odor, volatile at
atures and boiling at 113° and forming colorless crystals
le even at 300°. Hydrazine and its salts have a strong

alts. Hydrazine combines with acids by addition, forming
ts which we may consider as being formed by the bivalent
nium, $-H_3N-NH_3-$, replacing 2 H atoms of the acid
$SO_4=(N_2H_6)SO_4$, or that the univalent radical, H_4N-NH-,
tom of the acid, thus: H_4N-NHI, $(H_4N-NH_2)SO_4$; these
the most stable. Diammonium sulphate, $(N_2H_6)_2SO_4$,
ccount of its insolubility from solutions of all the other
by treating them with sulphuric acid.

Acid, . *Preparation.* 1. An ice-cold solution of
(HNO_2) is poured into an ice-cold solution of hydrazine:
$=N_3H+2H_2O$.

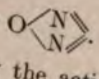
nia (NH_3), when heated with metallic sodium, yields sodium
, which when heated with nitrous oxide, N_2O, yields the
of hydrazoic acid: $2NH_2Na+N_2O=NaN_3+NaOH+NH_3$.
this salt with dilute sulphuric acid, we obtain an aqueous
hydrazoic acid.

e action of a solution of nitrogen trichloride in benzol (see
e) upon hydrazine: $N_2H_4+NCl_3=N_3H+3HCl$. The hydra-
us obtained can be made anhydrous by careful distillation
ent with calcium chloride.

es. Colorless, poisonous, caustic, strongly acid liquid, boiling
having an intolerable odor. With glowing bodies, but often
aneously, it explodes with great violence. Miscible with
water, and the aqueous solution can only be kept with safety;
s all metals which are soluble in HCl.

oates, or azides, are similar in every respect to the salts of hydro-
id with the exception that they all readily explode. Silver
ecipitates white silver hydrazoate, N_3Ag; mercurous nitrate
es white mercurous hydrazoate, N_3Hg.

bines directly with nitrogen only when the electric spark long time through a dry mixture of these gases. Red de gas, NO_2, is in part produced. If water is present, rite is produced (p. 148).

xide, Laughing-gas, N_2O or . *Preparation.* It is addition to nitric oxide by the action of 15 to 18 per acid upon zinc or tin (see p. 160): $4Zn+10HNO_3=$ $+5H_2O+N_2O$. It is obtained pure by heating ammonium $H_4NO_3=N_2O+2H_2O$.

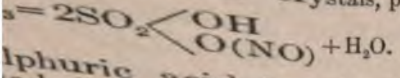
ties. Colorless and odorless, neutral gas, 1.52 times heavier vith a sweetish taste; it liquefies at −88°, forming a colorless ch solidifies to an ice-like mass at −103°. Glowing carbon or hosphorus burns in nitrous oxide the same as in oxygen ly burning sulphur is extinguished, as there is not sufficient rated to decompose the gases into N_2+O. With an equal f hydrogen it explodes when ignited: $N_2O+2H=H_2O+2N$; ot combine with oxygen. One volume of water dissolves volumes of this gas; on account of this property and because ot yield red nitrogen dioxide with nitric oxide, it can be ifferentiated from oxygen. When nitrous oxide is inspired es insensibility, and on account of the condition thus pro- has been called laughing-gas.

allic sodium is heated with an enclosed volume of nitrous oxide, ito sodium oxide, and a volume of pure nitrogen remains corre- to the volume of N_2O used. As 2 volumes of nitrous oxide parts by weight, and 2 volumes of nitrogen=28 parts by weight, ombined oxygen must weigh 16=1 volume, and hence nitrous st have the formula N_2O.

itrous Acid, Nitrosylic Acid, HNO, more correctly $H_2N_2O_2$, or N-OH. It is not produced from N_2O+H_2O, but, on the decomposes into these (see below). It is obtained in solution ction of nitrous acid upon hydroxylamine: $HNO_2+NH_2OH=$ H_2O, and in the anhydrous form by treating silver hyponitrite, (see below), with a solution of HCl in ether, when $Ag_2(NO)_2$ es into AgCl and free $H_2N_2O_2$. The liquid obtained on the on of the ether is readily explosive, thick, and solidifies on ito colorless crystals.

nitrites are produced by the action of potassium amalgam aqueous solutions of the nitrate or nitrite; by precipitating i salts with silver nitrate we obtain pale-yellow silver hypo- On decomposing the salts with sulphuric acid, the hyponitrous free immediately decomposes in part into H_2O+N_2O and in rding to the equation $3H_2N_2O_2=2N_2O_3+2NH_3$.

respectively NO_2+NO, with the forma-
ad chamber crystals, p. 128).



$$s=2SO_2\begin{cases}OH\\O(NO)\end{cases}+H_2O.$$

lphuric acid in sulphuric acid is called
ed, is very stable.

)=N−OH. *Occurrence.* As ammonium
extent in the air, in rain-water, in many
ned to a slight extent on the evaporation
action of the electric spark upon moist
torms), in all combustion processes in the
ion of phosphorus in the air, on rusting of
sis of water containing air: $2N+2H_2O=$
nitrites in many plant juices, nasal mucus,

operties. Liquid nitrogen trioxide mixes
ce-cold water, producing a blue liquid, which
HNO_2 in solution, but which decomposes at
or in the presence of considerable water:
H_2O.

able; they are produced by saturating the
O_2 with bases, oftener by carefully heating
e. With sulphuric acid, they develop red-
le gas mixed with colorless nitric oxide
id removes the water from the nitrous acid
$+NO+NO_2$. Weak acids set nitrous acid
oses immediately into $HNO_3+2NO+H_2O$.
mposition products have an oxidizing action,
gments and set iodine free from iodine salts:
$2I+2NO$. On the other hand, the nitrites,
dency to be converted into nitrates, have a
they decolorize acidified solutions of potas-
$HNO_2+2KMnO_4+3H_2SO_4=5HNO_3+K_2SO_4+$

eous solution of nitrites on acidification with
ch paste and potassium iodide blue.
ne gives an intense yellow with nitrite solu-

s the same reaction as with nitric acid.

ry widely diffused, although not in large quantities,
of the earth, especially in Egypt and India. It is
ium nitrate, $Ca(NO_3)_2$, or so-called wall saltpeter, on
ables and urinals. Nitrates are formed in all decomposi-
es of organic nitrogenous substances (see Nitrates); also
s contain nitrates.

ation. By distilling alkali nitrates, chiefly Chili salt-
h sulphuric acid at a temperature not above 220°:

$$\underset{\text{Sodium nitrate.}}{NaNO_3} + H_2SO_4 = \underset{\text{Sodium bisulphate.}}{NaHSO_4} + HNO_3.$$

crude nitric acid thus obtained contains 61–65 per cent. HNO_3
s a specific gravity of 1.36–1.40, and the pure nitric acid of
erce is obtained from this by redistillation and contains 68
nt. HNO_3 (see below).
in the distillation the temperature rises above 220°, then the
m bisulphate decomposes a second molecule of the nitrate:
$SO_4+NaNO_3=Na_2SO_4+HNO_3$; the temperature in this case
nes so high that a part of the nitric acid decomposes, $2HNO_3=$
$+2NO_2+O$, and red, fuming nitric acid is obtained.

nhydrous nitric acid is obtained by distilling pure nitric acid with con-
ated sulphuric acid, and removing the nitrogen oxides produced
assing air through the distillate.

Properties. Anhydrous nitric acid is a colorless, fuming liquid
ng an irritating odor and a specific gravity of 1.54, forms a crys-
ne solid at −40°, and begins to boil at 86° with a partial decom-
tion into H_2O+2NO_2+O, and miscible with water in all propor-
s. If dilute nitric acid is distilled, the boiling-point gradually
until it is 121° (p. 53), when nitric acid distils over which con-
s 68 per cent. HNO_3 and has a specific gravity of 1.41. Stronger
ic acids on heating give off HNO_3 until a 68 per cent. acid is pro-
ed.

Nitric acid vapors, on being passed through a red-hot tube, decom-
e into nitrogen dioxide, water, and oxygen (see above); this
omposition takes place in part on heating and on standing in the
light; hence nitric acid gradually becomes yellow. It contains 76.1
cent. oxygen, which is in part readily given off to oxidizable bodies;
re nitric acid is one of the strongest oxidizing agents and destroys

ogenous substances undergo es and air. It has been shown accumulate, which have the prop- produced in the decay into nitric acid ms): $KOH+NH_3+4O=KNO_3+2H_2O$. ditions for nitric acid formation are present in nearly all is the reason why soluble nitrates are found in spring-water er layers of the earth, especially in the neighborhood of the other hand, a series of bacteria are known which can itric acid formed into nitrous acid, ammonia, and indeed . These so-called saltpeter-destroyers are the cause of the en in the decomposition of manure on the manure-heap.

are nearly soluble in water; on strongly heating the es are decomposed into nitrites with the setting free of other nitrates decompose into the oxide of the metal NO_2+O. The nitrates are also strong oxidizing agents; d-hot carbon they all explode. By nascent hydrogen nitrates are reduced to nitrites or ammonia (p. 148). 1. Copper is dissolved by nitric acid with the pro- ue copper nitrate and the development of red nitrogen . The nitric acid is first set free from the nitrates on of sulphuric acid. ution of nitric acid or nitrates is mixed with concen- ic acid and a cold solution of ferrous sulphate floated ring forms between the two solutions.

cid oxidizes a part of the ferrous sulphate into ferric itric oxide is formed, which gives a brown color with mposed ferrous sulphate (p. 156):

$$_4+3H_2SO_4+2HNO_3=3Fe_2(SO_4)_3+4H_2O+2NO.$$

s solution of diphenylamine in sulphuric acid is colored aces of nitric acid, and also by NO_2, HNO_2, and other ces.

2. Phosphorus.

Atomic weight 31=P.

Only in the form of phosphates, that is, salts of H_3PO_4. These occur in the mineral kingdom espe- phosphate, $Ca_3(PO_4)_2$; in many varieties of rocks

ineral phosphates with carbon and a flux in
form as a vapor, which is condensed by passing
is purified by redistillation, and then melted
nerally moulded in the form of sticks in glass

sphorus is a transparent, crystalline, faintly
sonous body which is brittle when cold, and at
res as soft as wax and having a faint garlic-like
t has a specific gravity of 1.83, melts at 44°, boils
forms colorless vapors whose vapor density is 62,
ws that its molecular weight is 124 (p. 21). As its
ly 31, then the phosphorus molecule in the vapor-
sist of 4 atoms.

insoluble in water, slightly soluble in ether and
uble in fatty oils (*oleum phosphoratum*) and carbon
aporation of the solution (in the absence of air,
otherwise) we obtain the phosphorus in regular
a; it shines in the dark (φῶς, light, and φόρος,
in moist air (vapors of P_2O_3) with the generation
whereby it is oxidized and forms phosphorous
phosphoric acid (H_3PO_4), and at the same time
ozone, and hydrogen peroxide are formed. Even
nd burns with a dazzling white flame into phos-
P_2O_5); the ignition may take place even on lying
riction; hence it must be kept under water and
under water. It must also be kept in the dark,
r water it becomes covered with a layer of phos-
O.

phosphoric acid (p. 167) on warming with nitric
and with caustic alkalies it forms, on warming,
osphorous acid (p. 165).

bines with the halogens even at ordinary tem-
development of flame, and with most metals on
g phosphides. It has, especially when finely
educing action and separates many metals (or
om their salt solution; hence paper moistened
nd exposed to an atmosphere containing traces

SPHORUS.

a. *Compounds with Hydrogen.*

Gaseous phosphureted hydrogen, PH_3.
Liquid phosphureted hydrogen, P_2H_4.
Solid phosphureted hydrogen, P_4H_2.

osphureted Hydrogen, Hydrogen Phosphide, Phos
reparation. 1. Analogous to arseniureted hydrogen,
te sulphuric acid, zinc, and phosphorus.
ing phosphorous acid (H_3PO_3) or hypophosphorous
${}_3PO_3 = PH_3 + 3H_3PO_4$ (phosphoric acid);
${}_3PO_2 = PH_3 + H_3PO_4$
omposing calcium phosphide with water or dilute
acid: $Ca_3P_2 + 6HCl = 3CaCl_2 + 2PH_3$.
rily by boiling phosphorus with alkali hydroxide solu-
$+ 4P + 3H_2O = PH_3 + 3KH_2PO_2$.
hosphonium iodide (see below) by heating with alkali
ion: $PH_4I + KOH = PH_3 + KI + HOH$.

The phosphureted hydrogen gas obtained according
to 4 always contains small amounts of hydrogen and
ureted hydrogen, P_2H_4, which is spontaneously inflam-
ich condenses when the gas is passed into a tube sur-
n ice mixture, or is decomposed by passing the gas
chloric acid or alcohol. Pure PH_3 is a colorless, poison-
s which is insoluble in water, has a garlic-like odor, and
6° and solidifies at −134°. It does not inflame spon-
inflames with chlorine and bromine vapors, and with
s it yields spontaneously inflammable P_2H_4. When
urns into water and phosphoric anhydride (P_2O_5),
te smoke which often forms rings that rise. In
n to NH_3 phosphureted hydrogen has only weak
, as it unites directly only with HBr and HI, form-
hosphonium compounds for instance phosphonium
ith HCl it unites only at −35°. It has a reducing
e separates the pure metal or the metallic phosphide
allic salt solutions.

spark is passed through a tube filled with PH_3, amor-
s separates, the volume of the gas increases one-half

us acid, H_3PO_2, is produced by decomposing barium 165, 4) with sulphuric acid. The solution obtained the barium sulphate is concentrated by evaporation p receiver and forms a colorless, sirupy liquid which white plates at 0°:

$$\overset{\text{I}}{\text{a}}<\begin{matrix}H_2PO_2\\H_2PO_2\end{matrix}+\begin{matrix}H\\H\end{matrix}>SO_4=\begin{matrix}H_3PO_2\\H_3PO_2\end{matrix}+BaSO_4.$$

lecomposes into phosphorous acid and PH_3 (p. 165); on it is readily converted into phosphoric acid and is, there-educing agent. It reduces sulphuric acid to sulphur en into sulphur and precipitates gold and silver from etc. Only one of its hydrogen atoms can be replaced by erefore, a monobasic acid, having the formula $H_2PO(OH)$. *ites* are produced on warming an aqueous solution of the sphorus; they have a reducing action and hence are readily phosphates.

trioxide, P_2O_3 (according to its vapor density, phos-de, P_4O_6, formerly erroneously called phosphorous anhy-luced on passing a slow current of dried air over gently orus and forms a volatile, white amorphous powder which lized into P_2O_5 and which dissolves in water with the separa-ow amorphous powder (perhaps P_2O). On heating to 400° it into phosphorus and

us tetroxide, P_2O_4, the anhydride of hypophosphoric acid, colorless needles.

osphoric acid, $H_4P_2O_6$, is only known in aqueous solution uced when moist phosphorus is exposed for a long time to the characterized by its difficultly soluble acid sodium salt, which is used in the separation of this acid from the phos-id and phosphoric acid produced at the same time.

orous acid, H_3PO_3, is formed beside phosphoric acid and horic acid in the slow oxidation of phosphorus in moist air, be obtained pure by decomposing phosphorus trichloride with $Cl_3+3H_2O=H_3PO_3+3HCl$. If the solution obtained is evap-der the air-pump receiver, phosphorous acid separates in color-quescent crystals which melt at 70°, and on further heating se into phosphoric acid and PH_3 (p. 165). Analogous to H_3PO_2 up oxygen and is readily converted into phosphoric acid, and ts like a very strong reducing body. Only two of its hydrogen n be replaced by metals, therefore it is a bibasic acid having ula $HPO(OH)_2$.

phites are also strong reducing agents, but are not oxidized in

sphorus pentoxide, phosphoric anhydride, P_2O_5, is produced hosphorus is burnt in a strong current of dry oxygen or air s white, neutral, flocculent masses which have a greenish orescence in the dark and which readily absorb moisture and sce, forming metaphosphoric acid (process, p. 168). Because

a. Compounds with Hydrogen.

Gaseous arseniureted hydrogen, AsH_3.
Solid arseniureted hydrogen, As_4H_2.
Liquid arseniureted hydrogen, As_2H_4,

is not known free, but derivatives of the same, containing hydrocarbon groups such as cacodyl, $As_2(CH_3)_4$ (see Part III), are known.

Gaseous Arseniureted Hydrogen, Arsenic Hydride or Arsine, AsH_3.

Preparation. 1. It is obtained pure by the action of dilute sulphuric acid or hydrochloric acid upon an alloy of arsenic and zinc: $As_2Zn_3 + 6HCl = 2AsH_3 + 3ZnCl_2$.

2. Mixed with hydrogen it may be obtained by the action of nascent hydrogen upon dissolved arsenic compounds. If a solution containing arsenic, but free from nitric acid (p. 173), is introduced into a flask in which zinc and dilute sulphuric acid are present, we obtain the gas which may be dried by passing over solid calcium chloride (Marsh apparatus).

Properties. Colorless, very poisonous gas, having a garlic-like odor, liquefiable at $-56°$ and solid at $-114°$ and which does not combine with acids, but itself shows acid-like characters (p. 173). When ignited it burns into arsenic trioxide and water: $2AsH_3 + 6O = As_2O_3 + 3H_2O$; if a cold object, for instance a porcelain dish, is held in the flame, this is then cooled down below the combustion (oxidation) temperature of the arsenic, which does not burn into its oxide, but deposits as brownish-black, shining spots, so-called "arsenic-stains," upon the porcelain.

Arseniureted hydrogen is decomposed into arsenic and hydrogen by the electric spark or by a faint white heat; hence if the gas is passed through a heated glass tube, the arsenic deposits as a black shining coating, so-called "arsenic mirror," after having passed th heated portion of the tube.

Arsenic stains and arsenic mirrors consist of brown arsenic (p. 17 they volatilize on heating without melting; they readily dissolve sodium hypochlorite solution; when touched with nitric acid t dissolve, forming arsenic acid or arsenious acid; if this solutio neutralized with ammonia and treated with silver nitrate solu brownish-red silver arsenate or yellow silver arsenite are prod (differing from antimony-stains, p. 179).

se compounds are soluble in
AsO₃ (behaves towards arsenious acid like meta-
osphoric acid, $H_3AsO_3=HAsO_2+H_2O$), is not
s are known.

, arsenic anhydride, As_2O_5, is obtained by
senic Tetroxide) arsenic acids (which see) as a
ich on boiling with concentrated hydrochloric
enic trichloride and free chlorine, as the arsenic
decomposes immediately:

$$_5+10HCl=2AsCl_5+5H_2O;$$

$$2AsCl_5=2AsCl_3+4Cl.$$

and is slowly converted into orthoarsenic acid:

$$As_2O_5+3H_2O=2H_3AsO_4.$$

As_2O_4. Arsenic pentoxide melts on strongly heat-
of oxygen and forms a viscous, yellow liquid, As_2O_4,
ms an amorphous, vitreous mass that decomposes
onger heating.

d, H_3AsO_4, arsenic acid, is prepared by warming
trioxide with aqua regia or with concentrated

$$NO_3+2H_2O=3H_3AsO_4+5NO;$$

$$HNO_3+2H_2O=2H_3AsO_4+NO+NO_2.$$

solution, colorless rhombic crystals having the
$+H_2O$ separate out.

logous to the salts of orthophosphoric acid and
therewith. Silver nitrate precipitates reddish-
, Ag_3AsO_4, from their solution, and this precipi-
monia and nitric acid. Precipitates analogous
e also obtained on warming with ammonium
agnesia mixture.

$_4As_2O_7$, is obtained as crystals by heating arsenic
$=H_4As_2O_7+H_2O$.
sO_3, is produced as a crystalline mass by heating
cids to 200°.
of these acids in water they yield orthoarsenic

. Antimony-stains are, contrary to the arsenic-stains, , nearly black, insoluble in sodium hypochlorite solution, re after oxidation with nitric acid and neutralization with ia a black stain of antimony silver, $SbAg_3$, with silver nitrate n. On passing SbH_3 into silver nitrate solution all the anti- precipitates as $SbAg_3$.

b. *Compounds with the Halogens*

prepared like the corresponding phosphorus compounds. They with many metallic chlorides readily soluble, crystalline double salts, h are used as mordants in dyeing: thus, $NaCl+SbCl_3$.

Antimony Trichloride, Antimonous Chloride, $SbCl_3$. *Preparation.* dissolving antimony oxide or antimony sulphide in hydrochloric : $Sb_2S_3+6HCl=2SbCl_3+3H_2S$. This is then distilled, when H_2S, then the excess of hydrochloric acid, and finally the antimony hloride pass over.

Properties. Colorless, fuming, crystalline, caustic, soft masses nce formerly called butter of antimony), which melt at 73° boil at 223° and which absorb water from the air and deliquesce. imony chloride is soluble in hydrochloric acid; if this solution solid antimony chloride is treated with considerable water, a te crystalline precipitate of

Antimony oyxchloride, SbOCl, is obtained. This was formerly ed Algarot powder. It contains various amounts of antimony xide according to the method of preparation:

$$2SbCl_3+3H_2O=Sb_2O_3+6HCl;$$
$$SbCl_3+H_2O=SbOCl+2HCl.$$

Antimony pentachloride, antimonic chloride, $SbCl_5$, is a yellowish ning liquid which crystallizes at −6° and which with a little water idifies into crystals having the composition $SbCl_5+H_2O$ or $SbCl_5+$ $_2O$, and with more water deposits ortho- or pyroantimonic acids . 180).

c. *Compounds with Oxygen.*

Antimony trioxide,	Sb_2O_3.	**Antimonous acid,** **Metantimonous acid,**	H_3SbO_3. $HSbO_2$.
Antimony pentoxide,	Sb_2O_5.	**Orthoantimonic acid,** **Metantimonic acid,** **Pyroantimonic acid,**	H_3SbO_4. $HSbO_3$. $H_4Sb_2O_7$.
Antimony tetroxide,	Sb_2O_4.		

d. *Compounds with Sulphur.*

ulphide, Sb_2S_3, occurs in gray, brittle, crystalline
It is a constituent of many minerals, such as
gyrite, bournonite, etc. (see below). It is readily
at higher temperatures.
ned as an amorphous orange-red powder by pass-
drogen into antimony trichloride solution: $2SbCl_3+$
l. It is soluble in alkali sulphides (see below)
nd crystalline on heating in the absence of air.

lphide, Sb_2OS_2, is found in nature as kermesite, and
ting stibnite with an insufficient supply of air. It
d vitreous mass (antimony vermilion). A mixture of
e and antimony trioxide is called *kermes.*

tasulphide, Sb_2S_5, gold sulphur, is obtained by
ted hydrogen into a solution of antimony penta-
$-5H_2S = Sb_2S_5 + 10HCl$, or by decomposing sodium
, Na_3SbS_4 (which see), with acids. It is an orange-
ble in alkali sulphides (p. 182), and decomposes on
$_3 + S_2$.

d Sulphosalts of Antimony. Like the sulphides of
ides of antimony form compounds with metallic sul-
derivatives of the following acids unknown in the free

Sulphantimonous acid, H_3SbS_3;
Sulphantimonic acid, H_3SbS_4.

se acids are obtained in a manner analogous to that of
these salts are also found in the following minerals.

yrite, $\overset{I}{Ag_3}SbS_3$, Bournonite, $(\overset{II}{Pb}\overset{I}{Cu})SbS_3$,

edrite group or Fahl ores, $\overset{II}{M_3}(SbS_3)+\overset{II}{M}S=\overset{II}{M_4}Sb_2S_7$,

$_2$, in part $\overset{I}{Ag_2}$, $\overset{II}{Fe}$, $\overset{II}{Zn}$, $\overset{II}{Hg}$; thus, $(\overset{I}{Cu_2})_3(\overset{I}{Ag_2})Sb_2S_7$.

e. *Detection of Antimony Compounds.*

e obtainment of an antimony mirror on heating the
ted hydrogen gas produced (p. 178).
e antimony salts give with water a white precipitate of
ony salts, which are soluble in tartaric acid (differing
bismuth salts).

and to an enormous extent free in the atmosphere of the sun
name) and of the fixed stars.
ation. The powdered minerals are heated in order to remove
gases, which are less firmly combined than the helium. This
then heated with potassium dichromate in a vacuum, when
l argon are evolved; in order to separate these two gases, they
d in a Geissler tube with magnesium electrodes to a strong
rrent, when the argon is absorbed by the magnesium.
ies. Colorless, odorless, and tasteless gas, liquefiable at −250°
insoluble in water. Helium is 0.14 times lighter than the
ice as heavy as hydrogen. Its characteristic spectrum consists
ines of which six lie in the red, green, blue, and violet; the
hich is especially characterized, occurring in the yellow, and
he right of the yellow sodium lines.

BORON.

Atomic weight 11=B.

occurs only trivalent and belongs, from the constitution
pounds, to the nitrogen group, and from its position in the
stem, as well as the behavior of certain of its compounds,
to aluminum. Most of the boron compounds show great
to the corresponding silicon compounds. When free it
similarity to carbon and to silicon.

ence. Only combined as boric acid, H_3BO_3 (which see),
e tetraborates, such as tinkal or borax, $Na_2B_4O_7+10H_2O$, in
oracite, $4MgB_4O_7+2MgO+MgCl_2$ and borocalcite, CaB_4O_7+
ur in Stassfurt salt. Boron is also found to a trivial extent
plants.

ation. 1. By heating boron trioxide with magnesium when
s boron is obtained: $B_2O_3+3Mg=3MgO+2B$; the magnesium
duced is dissolved by hydrochloric acid.
stalline boron is obtained by heating amorphous boron or boron
vith aluminium: $B_2O_3+2Al=Al_2O_3+2B$. The boron dissolves
minium and crystallizes out on cooling; the aluminium is dis-
hydrochloric acid.
ties. *Amorphous boron* is a brown powder having a specific
2.45, burns on heating into boron trioxide, combines at higher
res with chlorine, bromine, sulphur, nitrogen, also with plati-
silver with the production of so-called borides. It has a reduc-
, hence explodes when rubbed with lead peroxides, decolorizes
permanganate solution, precipitates metallic silver from silver
ons, etc. It is oxidized into boric acid by boiling with nitric
ic acid: $2B+3H_2SO_4=2H_3BO_3+3SO_2$; on boiling with caustic
utions it dissolves with the formation of potassium metaborate:
$B+2H_2O=2KBO_2+6H$.

Properties. Colorless, shining laminæ having a specific gravity of .43, possessing a fatty touch, and which are soluble in 3 parts boilng and 25 parts cold water, as well as in alcohol. Boric acid is a very weak acid, but on account of the slight volatility of its anhydride it drives out most acids from their salts on heating therewith.

Detection. The lighted alcoholic solution burns with a green flame, and on boiling the aqueous solution the boric acid volatilizes with the steam. Boric acid solutions color blue litmus paper faint red, turmeric paper reddish brown on drying. (Alkalies turn turmeric paper brown immediately, and acids change this brown into yellow again. Boric acid only produces a brown stain after drying, which s not changed by acids and becomes greenish black with alkalies).

Borates. These are all derived from tetraboric acid; only organic salts of orthoboric acid are known. The salts of metaboric acid are very unstable. All borates give the reactions mentioned for boric acid if they are treated with hydrochloric acid for the turmeric reaction and with sulphuric acid for the flame reaction.

Metaboric acid, HBO_2, is obtained by heating orthoboric acid to 100°: $H_3BO_3 = HBO_2 + H_2O$.

Pyro- or Tetraboric Acid, $H_2B_4O_7$, is produced on heating ortho- or metaboric acids to 140°: $4H_3BO_3 = H_2B_4O_7 + 5H_2O$;

$$4HBO_2 = H_2B_4O_7 + H_2O.$$

Perboric acid, HBO_3, is known only in the form of salts, which are obtained from solutions of the tetraborates by H_2O_2. They are energetic oxidizing agents.

CARBON GROUP.

Carbon. Silicon.
Germanium. Tin. Lead.
Titanium. Zirconium. Cerium. Thorium.

The elements of the first two series are di- and tetravalent; lead generally occurs divalent; the elements of the last series are tetravalent only.

Germanium, tin, lead, bear the same relationship to carbon and silicon that arsenic, antimony and bismuth do to nitrogen and phosphorus. As the atomic weight increases, the character of the elements becomes more metallic:

$$\begin{array}{ccccccccc} & +17 & & +44 & & +45 & & +88 & \\ N=14 & & P=31 & & As=75 & & Sb=120 & & Bi=208 \\ & +16 & & +44 & & +46 & & +89 & \\ C=12 & & Si=28 & & Ge=72 & & Sn=118 & & Pb=207 \end{array}$$

The elements of the second and third series show even more metallic character than arsenic and antimony, and will be discussed with the metals. They do not combine with hydrogen, but, on the co combine with the halogens, forming volatile compounds. Their oxides are bases, while their dioxides are acid anhydrides.

1. Carbon.

Atomic weight 12=C.

Occurrence. Free in three allotropic modifications as dia graphite, and amorphous carbon, which in their properties sh greatest differences and are only correspondent with each other t the fact that they all yield carbon dioxide, CO_2, on burning. It combined as the chief constituent of all animal and plant subs and the products, such as peat and various coals, produced slow decomposition of plant substances. Combined with hydr forms rock-oil (petroleum) and asphalt; as carbon dioxide it combined with oxygen in the air and in the carbonates, such as n limestone, chalk, dolomite, often forming entire mountains.

Preparation. See the individual modifications.

Properties. Solid, odorless, and tasteless, soluble only in iron, not fusible, only volatile at about 3500° in the electri At ordinary temperatures it remains unchanged; at higher te tures it burns into carbon dioxide with the development o and heat and leaves an ash which consists of admixed inorgani stances. At a white heat amorphous carbon abstracts the from most bodies and is, therefore, a powerful reducing agent.

Carbon combines with fluorine even at ordinary temper with oxygen, sulphur, and iron at a red heat; and with hyd boron, silicon, and most metals, on the contrary, at about Its compounds with silicon, boron, and the metals are called c and are characterized by their stability and non-fusibility highest temperatures which have been obtained up to the time. These carbides generally form beautiful crystalline masses are decomposed by acids and, with the exception of iron c chromium carbide, and titanium carbide, are decomposed by w

Diamond occurs in regular rhombodecahedra, seldom as hedra, generally with curved surfaces and edges. It has a specific g of 3.5, is transparent, generally colorless, sometimes red, green and black, readily pulverizable, is a non-conductor of electricity poor conductor of heat. The diamond possesses the greatest bri

odies has the highest refractive power, as well as the
dness, as it can only be polished with its own powder
ıen heated in oxygen it burns into carbon dioxide;
ly heated in the absence of oxygen it is converted into
en the strongest oxidizing agents do not attack it. Dia-
be obtained in microscopic crystals by dissolving car-
en iron and cooling the mixture under great pressure.

, plumbago, black lead, occurs chiefly as amorphous, scaly
k masses which, when rubbed on paper, leave a mark,
in the lead-pencil manufacture and as iron paint (stove-
seldom occurs in the crystalline state except as gray
lates. It has a specific gravity of 2.25, conducts heat
ty well, is more difficult of combustion in an oxygen
the diamond, but is oxidized by strong oxidizing agents
c acid, $C_{11}H_4O_5$, or mellitic acid, $C_{12}H_6O_{12}$.
ficially obtained by melting amorphous carbon with iron,
rbon dissolves and separates out in black plates on
iron.

ous carbon is obtained by heating many organic sub-
) in the absence of air, when the volatile carbon com-
riven off and a part of the carbon mixed with the inorganic
remains behind. It forms a black, voluminous powder, or
k opaque compact masses which have differing specific

lack is obtained by burning substances such as turpentine,
hich are very rich in carbon with an insufficient supply of
purest form of amorphous carbon and is used in the prepara-
ink and printing-inks.

harcoal is obtained by the carbonization of wood in heaps
els (in the dry distillation of wood). It shows the structure
nd is porous, hence a poor conductor of heat and electricity.
ses, pigments, bitter principles, alkaloids, and many metallic
ıeir solutions. One volume of wood charcoal absorbs 90
mmonia or 9 volumes of oxygen. Because of this property
he filtration of water, in the absorption of putrefactive gases,
usilization of alcohol. Freshly heated wood charcoal inflames
ntaneously, as in the absorption of oxygen heat is set free.

l charcoal, bone-black, ivory-black, is obtained on the car-
f animal bodies (blood-carbon, bone-carbon). It absorbs
g matter, etc., with greater activity than wood charcoal, as
mixed with considerable mineral matter and hence is very
d.

rbon, retort graphite, deposits, in the manufacture of illumi-

etorts. It is very hard and dense, a good
used in galvanic batteries.
rts in the manufacture of illuminating-gas.
y.

produced from prehistoric plants by a
nization, where the hydrogen and oxygen go
d the longer the process goes on the greater
, until finally the plant structure disappears
60 per cent. carbon, brown coal 70 per cent.,
nd anthracite coal 95–98 per cent. carbon.

ompounds with Hydrogen.

gen unite directly and indeed at high tem-
y acetylene, C_2H_2, methane, CH_4, ethane, C_2H_6;
known compounds of carbon and hydrogen is
e seen later in Part III.

carbon may be derived from the hydrocarbons, as
be replaced completely or in part by other atoms or
For these reasons the chemistry of the hydrocarbons
es is treated of in a special part, and the old term
y" has been retained for this part.

b. Compounds with the Halogens

directly by the action of the halogens upon the hydro-
ill be considered in this connection.

c. Compounds with Oxygen.

monoxide, CO.
n dioxide, CO_2.
Carbonic acid, H_2CO_3.

Monoxide, CO. *Formation.* 1. In the combustion of
th an insufficient supply of air, as in furnaces or stoves
d dampers, or by burning charcoal in braziers, in illuminat-
nd also in the so-called generator gases.

e latter are produced for technical purposes in specially con-
furnaces (generators) by the insufficient combustion of deep
of carbon with air, and consist chiefly of carbon monoxide and
n. Dowson's gas is a mixture of generator-gas and water-gas
89).

reparation. 1. By passing carbon dioxide over heated carbon
lume of the gas is doubled:

$$= 2\text{ vol.} \qquad \underbrace{2\text{ mol.} = 4\text{ vol.}}_{2CO.}$$

CO₂ over red-hot zinc-dust or by h
or calcium carbonate, when the l
magnesium oxide and carbon dioxi
powder, thus: $Zn + CaCO_3 = Z$
by heating oxalic acid ($C_2H_2O_4$
$H_2O + CO_2 + CO$. The gaseous mix
a watery solution of potassium
CO_2, while the CO passes through u

may also be obtained by warmi
such as citric acid, malic acid, for
see) with sulphuric acid. Carbo
changes.

an excess of carbon with va
$+CO$.

steam over heated carbon a mi
(water-gas) is obtained: $C + H_2O$
when the electric arc passes

Colorless and odorless, n
and which liquefies at −1
quickly absorbed by a s
acid or ammonia. Whe
characteristic) into ca
of bodies, but o
strong reducing age
even in small
hæmoglobi
explodes on ig
bromine, for

with fine
carbony
with potas
CO

on since the elimination of carbon dioxide from the lungs is y much slower because of the diminished diffusion. If potassium magnesium is heated in CO_2, they are oxidized and the carbon arates as amorphous carbon. At −80° or at 0° and a pressure 39 atmospheres (p. 41) it is converted into a colorless neutral aid which is not miscible with water and has a specific gravity 2 and occurs in commerce in wrought-iron cylinders.

If liquid carbon dioxide is allowed to flow out in a thin stream, part becomes gaseous immediately and takes up so much heat at another part solidifies into snow-like flakes which melt at −65° der a pressure of 3.5 atmospheres; hence solid CO_2 passes immedi-ely into the gaseous state at ordinary temperatures (p. 35).

Solid carbon dioxide volatilizes only slowly on lying in the air, when temperature sinks to −78°. A mixture of the same with ether pro-ces, on evaporation, a temperature of about −90°; if this mixture is aporated under the air-pump receiver, its temperature falls to −140°.

One volume of water dissolves at 15° 1 volume carbon dioxide. he watery solution has a faint acid reaction, the dry gas itself being eutral. Carbon dioxide is readily absorbed by caustic alkalies, forming carbonates: $CO_2 + 2KOH = K_2CO_3 + H_2O$.

With the dark electric discharge in the presence of water or hydro-en CO_2 is converted into formic acid: $CO_2 + 2H = CH_2O_2$; $CO_2 + H_2O = CH_2O_2 + O$.

Its constitution can be determined by burning pure carbon in a known olume of oxygen, when on cooling, in place of the oxygen used, an equal olume of carbon dioxide is found. Two volumes of carbon dioxide, which eigh 44 parts, contain 2 volumes or 32 parts by weight of oxygen, and ence 44 − 32 = 12 parts by weight of carbon.

Carbonic acid, H_2CO_3 or $O{=}C{=}(OH)_2$, is not known free, but the queous solution of carbon dioxide may be considered as a solution f carbonic acid: $CO_2 + H_2O = H_2CO_3$. As H_2CO_3 is a weak acid, hence eutral salts formed with strong bases still have a basic reaction.

Carbonates may be obtained by saturating bases with carbon ioxide: $2KOH + CO_2 = K_2CO_3 + H_2O$; $K_2CO_3 + H_2O + CO_2 = 2KHCO_3$. They are decomposed, with effervescence, by every stronger acid, as the carbonic acid formed immediately decomposes: $K_2CO_3 + H_2SO_4 = K_2SO_4 + H_2CO_3$; $H_2CO_3 = H_2O + CO_2$.

Detection of Carbon Dioxide and Carbonates. If a glass rod moistened with a clear solution of barium or calcium hydrate is

Sulphocarbonates. As carbon dioxide unites with oxides, forming carbonates, so carbon disulphide combines with sulphides, forming sulphocarbonates; thus sodium sulphocarbonate is produced by dissolving carbon disulphide in sodium sulphide solution: $CS_2+Na_2S=Na_2CS_3$.

Carbon oxysulphide, COS, is found in mineral springs and is produced by passing sulphur vapors and carbon monoxide through a red-hot tube, or, better, by pouring sulphuric acid upon potassium sulphocyanide (KCNS), when sulphocyanic acid is set free which takes up water, forming carbon oxysulphide and ammonia: $HCNS+H_2O=COS+NH_3$. It is a colorless gas having an odor similar to sulphuretted hydrogen, readily inflammable, and burns into carbon dioxide and sulphur dioxide.

Monosulphocarbonic acid, H_2CO_2S $(=H_2O+COS)$ and
Disulphocarbonic acid, H_2COS_2 $(=H_2S+COS)$ are known only as salts.

e. Compounds with Nitrogen.

One compound called dicyanogen, NC–CN, is known which forms numerous other compounds. Dicyanogen cannot be obtained by direct union of the elements. Dicyanogen and its compounds will be treated of in organic chemistry.

2. Silicon, or Silicium.

Atomic weight 28.4 = Si.

Occurrence. Silicon is, next to oxygen, the most widely diffused of the elements, but does not occur free. Combined with oxygen, it is found as silicon dioxide or silica in the three natural kingdoms; silicates form many minerals and nearly all crystalline varieties of rocks (see Silicon Dioxide and Silicates).

Preparation. 1. By heating sodium fluosilicate with metallic sodium: $Na_2SiF_6+4Na=6NaF+Si$; this product is treated with water, which dissolves the sodium fluoride and leaves the amorphous silicon.

2. Alloyed with some magnesium it may be obtained by fusing sand (SiO_2) and magnesium powder together.

3. If zinc be added in this method of preparation, then the silicon dissolves in the molten zinc and separates on cooling as crystalline silicon, which remains on dissolving the zinc in hydrochloric acid.

Properties. Crystalline silicon forms black octahedra of a specific gravity 2.5, which scratch glass; it is not oxidized on heating in the air, and melts at about 1500°.

Amorphous silicon is a reddish-brown powder with the specific

ilicic acid, H_2SiF_6, is obtained. This is an acid, fu
iquid; it is not known in the anhydrous state; c
a platinum vessel it leaves no residue, as it decom
tile SiF_4 and 2HF. It forms salts, the silicofluorides,
SiF_6 and $BaSiF_6$ are insoluble in water, hence they
quantitative estimation of potassium and barium.

ide, SiS_2, is obtained by heating amorphous silicon with
orms silky prisms which are decomposed by water:
SiO_4+2H_2S.

xide, Silica, Silicic Anhydride, SiO_2. *Occurrence.* It
es the chief constituent of the earth's crust and is a
all plants and animals (see Silicic Acids). It occurs
talline as well as in the amorphous state.
silicon dioxide occurs as rock crystals in transparent,
gonal columns, and as quartz as colorless, opaque,
es. Both of these occur in many modifications, espe-

d topaz, when transparent and pale yellow.
hen transparent and violet by manganese.
z when transparent and colored brown or black by bitu-
r.
in hexagonal twin crystals.
artz when opaque, gray, or yellowish.
tz when opaque, milky white.
when opaque, rose-color.
nturine, chalcedony, chrysoprase, flint, heliotrope, jasper,
s-eye, onyx, tiger-eye, are mixtures of amorphous and crys-
dioxide having various colors and occurring as minerals.
the chief constituent of granite, syenite, and gneiss. In
rains (sand) quartz covers a great part of the earth's sur-
e consists of individual quartz granules which are united
ne other substance.

s silicon dioxide is found as opal in colorless or colored
s, and also in many vitrifications; tripolite or infusorial
of the siliceous shells of infusoria.
. Amorphous silicon dioxide is obtained by burning
on or by heating silicic acid. It forms white, soft
alline silicon dioxide is obtained by heating dialyzed
below) under pressure for a long time or by strongly
us silicon dioxide for a long time.

II. METALS.

For reasons given on page 95 the elements which are calle are divided into the following groups:

1. Potassium, sodium, cæsium, rubidium, lithium (ammo
2. Calcium, barium, strontium.
3. Beryllium, magnesium, zinc, cadmium.
4. Copper, silver, mercury.
5. Aluminium, gallium, indium, thallium, scandium, ytt lanthanum, cerium, praseodymium, neodymium, samarium, linium, erbium, thulium, ytterbium.
6. Tin, zirconium, titanium, thorium.
7. Bismuth, vanadium, tantalum, niobium.
8. Chromium, molybdenum, tungsten, uranium.
9. Iron, manganese, cobalt, nickel.
10. Gold, platinum, osmium, iridium, ruthenium, rhodi palladium.

Properties. The metals have more properties in common th the non-metals. The metals are non-transparent, and only cert of them are transparent in very thin layers. With the exception mercury they are all solids at ordinary temperatures.

When compact, especially when the surface is polished, th have a peculiar shine, which has been called metallic lustre. Wh finely divided they form dark powders. They are good conducto of heat and electricity. The color of most metals is white to bluis gray. Copper is red; gold, barium, and strontium are yellow. Mo metals are crystalline in regular systems. Only a few, having metalloid character, are not regular in their crystallization; thus bi muth crystallizes in the hexagonal system, and tin in the quadrat system.

The specific gravity of the metals is very different and variabl from 0.59, the specific gravity of lithium, to 22.5, the specific gravity osmium. Metals whose specific gravity is below 5 are called lig

above are called heavy metals. Most metals are
ugh and may be converted into foil and wire. Only
, which have metalloid character, are brittle.
are fusible. Mercury has the lowest melting-point,
potassium melts at 63°, zinc at 243°, copper at 1100°,
770°, iridium at 1950°, chromium at 2100°, osmium
metals can be converted into a vaporous state; their
responds to their fusibility. Mercury vaporizes at 360°,
1000°; platinum and the other difficultly fusible metals
rized in the electric furnace.
al in the compact condition is soluble as such. If the sol-
metal in acids or bases is evaporated, we obtain a salt or
n the contrary, numerous metals are soluble in water at
ent when they are precipitated from the solution of their salts
finely divided state (see Colloidal Solution, p. 53).
metals are as a rule more active chemically than the metalloids,
molecule of the metals consists only of an atom, while in the
oids the molecule must be first split into atoms. The metalloids
erefore more active in the nascent state than in the ordinary
ion, where the atoms have already united to form molecules
).

e combinations of the metals between themselves according
certain proportion by weight are called *alloys* (p. 49). These
lly have the average properties of the metals of which they are
osed, so that it is possible to obtain alloys by the selection of
le metals which have properties of technical importance. The
with mercury are called *amalgams*.

e color of the alloys is different according to the constituents; still
ndependent of the proportion of the metals; thus an alloy of copper
30 per cent. of tin is white, while with 30 per cent. zinc it is yellow.
ardness and toughness are generally greater than those of the individ-
etals, while the melting-point is lower, and often lower than that of
netal having the lowest melting-point; thus a mixture of 2 parts
uth, 1 part tin, and 1 part lead (Wood's metal) melts at 94°, while
bismuth melts at 270°, tin at 235°, and lead at 334°. The melting-
t of amalgams lies always above that of mercury. Acids often attack
s with greater difficulty than the constituents alone; still many alloys
dissolved by acids which would not dissolve the metals contained in
mixture.

The compounds of the metals with the non-metals do not have
properties of the metals. While the oxides of the non-metals

olet flame due to the volatilized potassium, 2K+
2H; when alloyed with mercury it decomposes water
uction of flame. It combines directly with the halo-
d phosphorus, with the production of flame, and when
rogen to 400° it combines, forming silver-like brittle
e, K_2H, which spontaneously inflames in the air and
s at about 420°. On account of its relationship to
rine potassium is used in the setting free of metals
and chlorine compounds.

a. *Compounds of Potassium.*

le, K_2O, is not known with certainty.
droxide, Caustic Potash, KOH.
. By the action of potassium on water (see above).
1. On a large scale by the electrolysis of an aque-
tassium chloride: $KCl+H_2O=KOH+H+Cl$.
uantities by boiling a solution of potassium car-
ed lime (calcium hydroxide); insoluble calcium
out and the solution contains potassium hydroxide:
$=CaCO_3+2KOH$. The solutions obtained in 1 and
in silver dishes, as the KOH acts upon iron and

hite, crystalline substance, the strongest of all
a red heat, and volatile without decomposition at
res. When exposed to the air it absorbs moisture
and at the same time absorbing carbon dioxide.
plant and animal substances and is therefore used
t. It is very soluble in water and alcohol; the alco-
called alcoholic potash. As these solutions contain
gest bases they precipitate most metals as hydroxides
eir solution; thus, $FeSO_4+2KOH=Fe(OH)_2+K_2SO_4$.

lphide, potassium sulphuret, K_2S, is obtained by fusing
ate with carbon, as an anhydrous, dark-red, crystalline
$C=K_2S+2CO_2$. It is very hygroscopic, has an alkaline
s oxygen and water from the air, and is converted into
lphate and potassium hydroxide:

$$2K_2S+H_2O+4O=K_2S_2O_3+2KOH.$$

KBrO$_3$+3C=KBr+3CO. On dissolving this in
evaporating to crystallization, we obtain the
less, shining cubes which are fusible and volatile
parts of water.
, KI, is obtained in an analogous manner to

ith considerable powdered iron under water, when
d and enough iodine is added to this solution until
Fe$_2$I$_8$(2FeI$_3$+FeI$_2$), is formed. This solution is
equivalent quantity of potassium carbonate and
n ferrous-ferric oxide precipitates and the dissolved
oration to crystallization:
I$_8$+4K$_2$CO$_3$=Fe$_3$O$_4$+8KI+4CO$_2$.
rms colorless cubes which are fusible and volatile
rt water. Aqueous solutions of potassium iodide
ly, and many iodine compounds which are insol-
as HgI$_2$, are also soluble therein.

rate, KClO$_3$. *Preparation.* 1. Besides KCl by
a hot concentrated caustic potash solution and
to crystallization when the more insoluble potas-
ates out first (p. 138).
on a large scale as follows: Warm milk of lime,
d with chlorine and the calcium chlorate formed
ssium chloride, Ca(ClO$_3$)$_2$+2KCl=CaCl$_2$+2KClO$_3$,
of potassium chloride (p. 104), when the chlorine
e is passed directly into the potassium hydroxide
de.

orless plates having a characteristic cooling
parts cold water and melting at 334°. On heat-
nt it decomposes into potassium chloride and
te, and oxygen is given off (p. 139). On heating
xygen is expelled and it is converted into potas-
egard to other properties of the chlorate see p. 138.

orate, KClO$_4$. It is prepared as described on p. 139,
a slight extent in Chili saltpeter, and forms colorless
ry insoluble in water and hence is readily freed from
de produced in its preparation by washing with

lorite, KClO, is known only as a watery solution
is used as a bleaching agent, especially for wine-

Occurrence. In many
alt springs, sea-water, and
ive scale by heating sodium chloride
manufacture of soda (p. 213) and hydro-
135):

$$2NaCl+H_2SO_4=Na_2SO_4+2HCl.$$

omposing dissolved magnesium sulphate (kieserite)
loride: $MgSO_4+2NaCl=MgCl_2+Na_2SO_4$.
s is only accomplished at low temperatures, and is per-
ssfurt during winter. The $MgCl_2$ produced remains in
Na_2SO_4 crystallizes out.
ng sulphur dioxide, air, and steam over heated sodium
eave's process): $2NaCl+SO_2+O+H_2O=Na_2SO_4+2HCl$.

Colorless prisms of the composition $Na_2SO_4+10H_2O$
6 per cent. water. On lying in the air they lose a
ter of crystallization and then become cloudy and

te melts at 33° and decomposes into a saturated solu-
hydrous Na_2SO_4. On further heating it loses its
zation completely and is converted into anhydrous

at 18° dissolves 20 parts, at 30° 200 parts, and at 33°
lt $Na_2SO_4+10H_2O$. Above 33° the solubility dimin-
263 parts are dissolved, at 100° 238 parts of the salt.
the fact that at 33° the anhydrous salt Na_2SO_4 is
es out, and at the same time a part of it as such goes
so that a condition is obtained where its solubility
sing temperatures. If a solution which is saturated
a lower temperature, no salt separates out, although
le therein (supersaturated solution, p. 52).

phate, $Na_2SO_4+H_2O$, is obtained by drying sodium

d salt is a mixture of sodium sulphate, sodium
hloride, and potassium sulphate.

hate, $Na_2S_2O_3$, sodium hyposulphite, is obtained
es or by boiling an aqueous solution of sodium sul-
of sulphur: $Na_2SO_3+S=Na_2S_2O_3$. It crystallizes
H_2O in prisms which are stable in the air and are
e. solution is decomposed by acids with the setting
of sulphur, p. 121) and sulphur dioxide: $Na_2S_2O_3+$
$S+H_2O$. It has a reducing action converting
d iodine into sodium salts: $2Na_2S_2O_3+2I=2NaI+$
rathionate, p. 124) and hence serves as "anti
g in order to remove the excess

in blowpipe analysis, as it gives characteristic co
etallic oxides.

arbonate, Na_2CO_3, **Soda.** *Occurrence.* Dissolved
in Asia, Africa, North America, and in certain minera
bad, Vichy). It occurs as an efflorescence on the soil
ungary, and South America. It is contained to a great
e ashes of certain sea-plants (especially in the varieties
nd Salicornia), as well as from seaweeds, from which it
ly prepared in the same manner as potassium carbonate
shes of land-plants.

ation. 1. **Leblanc's Method** (1794). Common salt is
th sulphuric acid (or SO_2, air, and steam are passed over NaCl,
when sodium sulphate and hydrochloric acid are produced.
is allowed to pass off and is absorbed by water.
sodium sulphate is fused at a red heat with chalk ($CaCO_3$)
d coal, when the sodium sulphate is first reduced by the carbon
odium sulphide: $Na_2SO_4+2C=Na_2S+2CO_2$. The sodium
le is then transformed by the calcium carbonate into sodium
ate and calcium sulphide: $Na_2S+CaCO_3=Na_2CO_3+CaS$.
e black mass thus obtained, called black ash, contains 30–45
ent. sodium carbonate, 30 per cent. calcium sulphide, besides
(CaO), undecomposed calcium carbonate, coal, and sand. It
viated with cold water, which dissolves the sodium carbonate.
he soda solution (lye) is evaporated, while a continuous flow
w lye is added, until sodium carbonate, as $Na_2CO_3+H_2O$, separates
and this removed as soon as formed. These crystals are heated
nove water and any organic matter mixed with them, and occurs
mmerce as calcined soda, or the crystals are recrystallized from
y solution and obtained as $Na_2CO_3+10H_2O$ (p. 214).

every kilogram of soda there remains from 1 to 1½ kilograms
lue, which contains all the sulphur derived from the sulphuric
ed. This residue by the action of the air develops sulphuretted
n, while the polysulphides produced dissolve when exposed to
that the air and water in the neighborhood of a Leblanc soda
re contaminated to a considerable extent. In more recent times
residue is treated with carbon dioxide, $CaS+H_2O+CO_2=$
H_2S; the sulphuretted hydrogen is either burnt with a dimin-
ply of air, when most of the sulphur separates out (p. 122), or
pletely burnt into sulphur dioxide, which is used again in the
n of sulphuric acid (Chance-Claus method of regenerating

Sodium bicarbonate, $NaHCO_3$, primary or acid sodium carbona lium hydrocarbonate (baking soda), separates out on passing carb oxide into a concentrated solution of sodium carbonate: Na_2CO_3 $_2O+CO_2=2NaHCO_3$. The cheaper varieties are prepared accor ng to the Solvay process (p. 214) as an intermediary product. It form crystalline crusts or a white crystalline powder having a faint alka line reaction and soluble in 12 parts cold water. The moist powder or the powder exposed to moist air loses carbon dioxide.

Sodium silicate is prepared in a manner similar to that of potassium silicate (p. 208). Its watery solution is called "water-glass."

b. Detection of Sodium Compounds.

1. They color a non-luminous flame intensely yellow. The spectrum of this flame shows a single bright-yellow line.

2. All sodium salts are soluble in water with the exception of disodium pyroantimonate ($Na_2H_2Sb_2O_7$), which is obtained as a white granular precipitate when a solution of a sodium compound is treated with a solution of dipotassium pyroantimonate.

3. Cæsium.

Atomic weight 132.9 = Cs.

4. Rubidium.

Atomic weight 85.4 = Rb.

Both of these elements occur only in combination, rather widely distributed, always together, but always in small amounts; thus in many plant-ashes, in several minerals, such as lepidolite, pollucite, triphylite, and many mineral springs, especially of Nauheim and Dürkheim, also in the mother-liquors of carnallite. They give characteristic spectral lines and hence their names.

They are both obtained by the electrolysis of their chlorides, and inflame spontaneously in the air when in large pieces, hence must be kept under petroleum. Cæsium has a specific gravity of 1.84, is soft, silvery in appearance, melts at 26.4°, boils at 270°, and the metal as well as its compounds gives a violet color to a non-luminous flame. The spectrum of this flame show two intense blue lines.

Rubidium, sp. gr. 1.52, is soft, silvery in appearance, melts at 38.5, boils at about 500°, and the metal and its compounds give a violet color to a non-luminous flame. The spectrum of this flame shows two dark red and two violet lines.

5. Lithium,

Atomic weight 7.03 = Li,

occurs only combined, very widely distributed, but always in very small quantities, as in many mineral waters (Baden-Baden, Carlsbad, Marienbad), and in the ashes of many plants, especially in tobacco and the common beet. Certain minerals, such as triphylite, lepidolite, petalite, amblygonite, contain as much as 4.5 per cent. lithium. It is obtained by the elec-

solution to dryness and subliming the residue, or by the sub
of sodium chloride with ammonium sulphate:

$$2NaCl+(NH_4)_2SO_4=2NH_4Cl+Na_2SO_4.$$

When sublimed it forms fibrous crystalline masses, an
crystallized from water it forms a crystalline powder. It is
and odorless, volatile on heating, without melting, dissolv
parts water, and is nearly insoluble in alcohol.

Ammonium bromide, NH_4Br, is obtained on the sublim
potassium bromide with ammonium sulphate, and forms whi
or a white crystalline powder which is readily soluble in wa
difficultly soluble in alcohol.

Ammonium iodide, NH_4I, is prepared from potassium ioc
ammonium sulphate and forms white deliquescent cubes which ar
soluble in alcohol. It splits off iodine in moist air.

Ammonium sulphate, $(NH_4)_2SO_4$, occurs as the mineral mas
It is obtained by saturating the ammoniacal liquor of the g
with sulphuric acid and forms colorless and odorless crystal
decompose at high temperatures. It is used as a valuable fe

Ammonium persulphate, $(NH_4)_2S_2O_8$, forms colorless prism
are readily soluble. It is prepared on a large scale being use
oxidizing agent (p. 131) and is also used in photography.

Ammonium nitrate, $(NH_4)NO_3$, produced by saturating a
of ammonia with nitric acid and evaporating this product.
colorless crystals which are soluble in water and which decomp
water and nitrous oxide (p. 155) when heated. It is used as an
when mixed with saltpeter and resins.

Ammonium nitrite, $(NH_4)NO_2$. In regard to formation an
rence see Nitrous Acid. It is obtained by mixing a solution
nitrite with an ammonium chloride solution, filtering off the silver
and carefully evaporating the filtrate. It forms colorless cr
masses which on heating yield water and nitrogen (p. 146).

Ammonium phosphates. Tertiary ammonium phosphate (N
secondary ammonium phosphate, $(NH_4)_2HPO_4$, and primary am
phosphate, $(NH_4)H_2PO_4$, are obtained in a manner similar to tha
corresponding sodium phosphates. On careful heating they
residue of metaphosphoric acid thus:

$$(NH_4)H_2PO_4=HPO_3+H_2O+NH_3.$$

Sodium-ammonium phosphate, $Na(NH_4)HPO_4+4H_2O$ (mic
salt), occurs in guano and stale urine (hence formerly called Sa
fixum). If 5 parts disodium phosphate and 2 parts diammonium ph
are dissolved in hot water and allowed to cool, colorless prisms
out:

$$Na_2HPO_4+(NH_4)_2HPO_4=2Na(NH_4)HPO_4.$$

le with very great difficulty in water, or are insoluble therein, while sulphides, like those of the alkalies, are readily soluble. The solu- of the hydroxides increases from calcium to barium, and the solu- of the sulphate diminishes from calcium to barium.

hey are called alkaline-earth metals because they have properties ar to the alkali metals as well as to the earthy metals.

heir specific gravity, their melting-point, their volatility and chemi- energy increase with their atomic weight. Thus calcium hydroxide carbonate are readily decomposed on heating, while barium hydroxide ot at all decomposed, and barium carbonate only with difficulty, the corresponding strontium compounds are intermediate in their avior.

Their salts are not decomposed by ammonia solution, in contradis- tion to the salts of the groups which follow.

With hydrogen they form hydrides, CaH_2, SrH_2, BaH_2, which are rless solids.

These metals combine with nitrogen at a red heat, forming nitrides, N_2, Sr_3N_2, Ba_3N_2, which with water suffer the following decomposition:

$$Ca_3N_2+6HOH=3Ca(OH)_2+2NH_3.$$

With the heat of the electric furnace they combine with carbon, form- carbides, CaC_2, SrC_2, BaC_2, which is the reason that the alkaline-earth als are not obtained on heating their oxides with carbon as the metal ch is set free immediately combines with the carbon.

1. Calcium.

Atomic weight = 40.1 = Ca.

ccurrence. Never free, but its compounds are found extensively, n in large quantities. Calcium carbonate and calcium sulphate ch see) occur as very large deposits and form the chief constituents e solids of spring- and river-waters. Calcium silicate is a constitu- of nearly all siliceous minerals, and calcium phosphate occurs in ite and phosphorite (p. 162). Calcium salts always occur in the t and animal organisms.

reparation and Properties. Calcium is obtained by the elec- ysis of fused calcium chloride or by heating calcium iodide with um. It is a silvery-white soft metal, harder than lead and having ecific gravity of 1.58 and melting at 760°, but, as it slowly oxi- s in dry air, it must like potassium be kept beneath petroleum.

a. Compounds of Calcium.

Calcium oxide, CaO, caustic lime, lime, burnt lime, is obtained heating to a red heat pure calcium carbonate (white marble), t on a larger scale by heating impure calcium carbonate (the lime- nes) in so-called limekilns. It forms hard, white, amorphous, aline masses which become crystalline at 2500° and fusible at er, being then called dead burnt plaster. Anhydrite does not bine with water.

Tertiary or Tricalcium phosphate, $Ca_3(PO_4)_2$ (also neutral cal- m phosphate), occurs as apatite and phosphorite (p. 162) and con- utes two-thirds of the bones of animals; it forms the chief mass the coprolites, phosphorites, osteolites, and certain varieties of ano, and is found in the ash of all animal and plant organs. It is oluble in pure water but, on the contrary, is partly soluble in water taining CO_2 or certain salts.

A basic calcium phosphate, $Ca_3(PO_4)_2+CaO$, is the chief constituent the Thomas slag obtained in the dephosphorization of iron and which an excellent fertilizer. Its value is dependent upon the fact that it es not have to be converted into soluble superphosphate like the her calcium phosphate, but is ground finely (Thomas phosphate), and readily decomposed by the carbonic acid and moisture of the soil.

Pure calcium phosphate is obtained by mixing a solution of disodium osphate treated with ammonia with a solution of calcium chloride. his precipitate is gelatinous and when dry forms a white, amorphous, lorless and tasteless mass.

Secondary calcium phosphate, $CaHPO_4+2H_2O$ (dicalcium phosphate), curs often in urinary calculi and sediments as microscopic crystals. It obtained as a white crystalline powder insoluble in water by mixing a lution of disodium phosphate with a calcium chloride solution.

Primary calcium phosphate, $CaH_4(PO_4)_2$ (monocalcium phosphate), is btained by treating tertiary or secondary calcium phosphate with sul- huric acid (p. 162, *a*), and separates out on the evaporation of the solution s colorless, deliquescent, acid-reacting scales. It is readily soluble in ater and hence is better suited as a fertilizer than the tertiary salt. Vhen mixed with gypsum it forms superphosphate, which is used as fertilizer.

Calcium carbide, CaC_2, is obtained by heating CaO with carbon in the lectric furnace. When pure it forms gold-like crystals, and in com- merce it forms grayish-black masses which with water and acids gener- te acetylene gas, C_2H_2 (which see).

Calcium Carbonate, $CaCO_3$. *Occurrence.* 1. Amorphous or not markedly crystalline as limestone; in crystalline granules as marble; n amorphous or crystalline granules combined with magnesium car- bonate as dolomite, $CaCO_3+MgCO_3$; amorphous as chalk; schistous- ike as lithographic stone, etc.

2. As calc-spar (calcite) in hexagonal crystals (rhombohedrons), and as aragonite in rhombic columns.

3. In all plant-ashes and in all animals, especially in the bones; n the urine of herbivorous animals, and in many pathological concre- ions, as in urinary calculi, etc. It forms the chief constituent of he corals, oyster-, mussel-, snail-, and egg-shells, and pearls.

s is obtained by dissolving small amounts of metallic
l glass. With cobaltous oxide a blue glass is obtained,
yellow, with cupric or chromic oxide an emerald-green,
xide a fluorescent greenish yellow, with manganese
ith sodium sulphide a brown, and with metallic gold
y-red glass. Black glass is simply deeply colored violet,
glass. Green or common glass (see 2) is decolorized
of manganese oxide (brownstone) or didymium salts
enium, as the violet color produced is complementary to
ilk-glass is obtained by adding bone-ash or stannic oxide

b. *Detection of Calcium Compounds.*

color the non-luminous flame yellowish red, and the
this flame shows an intense green and a violet line.
onium oxalate causes a white precipitate of calcium
n in very dilute solutions of calcium salts. This precipi-
luble in acetic acid and oxalic acid. Barium and stron-
are only precipitated by this reagent in very concentrated

phuric acid precipitates calcium salts only from concentrated
and not from dilute solutions, as the white precipitate of
lphate, $CaSO_4$, is soluble to a slight extent in water.

2. Strontium.

Atomic weight 87.6=Sr.

only combined and then as strontianite, $SrCO_3$, and as
$SrSO_4$. The yellow metal has a specific gravity of 2.5,
600°, is obtained by the electrolysis of fused strontium
nd is similar to calcium in properties.

a. *Compounds of Strontium.*

m **oxide,** SrO, is produced by heating strontium nitrate.
mass which with water generates heat and forms strontium

n **hydroxide,** $Sr(OH)_2$, which is soluble in 50 parts water,
ined as crystalline $Sr(OH)_2+8H_2O$ from this solution. On
composes into water and strontium oxide.
salts are prepared from strontium carbonate by treating
spective acid. In regard to their use in the manufacture of
ne-sugar.

b. *Detection of Strontium Compounds.*

give a beautiful crimson-red color to the non-luminous
fireworks), and the spectrum of this flame shows one
ne blue line.

MAGNESIUM GROUP.

Beryllium. Magnesium. Zinc. Cadmium.

These are divalent metals which are volatile on heating and which burn with a flame into oxides when air is supplied. Their specific gravity, fusibility, and volatility increase with their atomic weights. They do not oxidize on being exposed to dry air. Zinc and cadmium do not decompose water at the boiling temperature, beryllium and compact magnesium only with difficulty, while they all decompose water at a red heat. Their oxides, hydroxides, carbonates, and phosphates are insoluble in water, and their sulphates are readily soluble in water. The sulphides of beryllium and magnesium are soluble in water, while zinc and cadmium sulphide are insoluble therein. The oxides of beryllium and magnesium are not reduced to the metallic state by carbon. The carbonates and chlorides are readily decomposed to the basic salts on warming.

Their sulphates (with the exception of beryllium sulphate) form isomorphous double salts, which are readily soluble, with the alkali sulphates: $MgSO_4+K_2SO_4+6H_2O$. Their hydroxides are soluble in ammonia or ammonium salts.

1. Beryllium (Glucinum).

Atomic weight 9.1 = Be.

Occurs only combined in certain rare minerals; thus in phenacite, Be_2SiO_4, in chrysoberyl, $Be(AlO_2)_2$, and especially in beryl, $(Be_3Al_2)Si_6O_{18}$, which when colored green with chromium oxide forms the precious stone called the emerald.

The metal is prepared by heating its chloride with sodium or its oxide with aluminium. It forms a silver-white metal having a specific gravity of 1.8 and melting at about 1000°, and the metal with its salts gives no coloration to the flame and no spectrum. The copper alloy of beryllium gives a beautiful tone when struck and is used for technical purposes.

Ammonia or caustic alkali precipitates $Be(OH)_2$ from its sweet salt solution, this precipitate being soluble in an excess of caustic alkali. Ammonium carbonate precipitates $BeCO_3$, which is soluble in an excess of $(NH_4)_2CO_3$.

2. Magnesium.

Atomic weight 24.36 = Mg.

Occurrence. Only combined: 1. As carbonate in magnesite, $MgCO_3$, and dolomite, $MgCO_3+CaCO_3$.

2. As silicate, forming the minerals olivine, talc, soapstone, serpentine, meerschaum. Powdered talc, a white greasy powder, is used as a vulnerary powder. Magnesium-calcium silicate forms the minerals augite, hornblendes, and asbestus (amianthus); magnesium-aluminium silicate, chlorite and magnesium mica.

3. As sulphate and chloride in sea-water and in certain mineral waters, giving a bitter taste thereto. In the "abraum" salts (p. 202)

Magnesium chloride, $MgCl_2$. It occurs as stated on pages 221 and 228 and is obtained as a by-product in many chemical processes. It crystallizes with $6H_2O$, forming deliquescent crystals which on evaporation decompose and are used in the manufacture of hydrochloric acid and chlorine (p. 133). It may be obtained in an anhydrous form by heating the magnesium chloride containing water in the presence of NH_4Cl or in a current of hydrochloric acid.

Magnesium sulphate, $MgSO_4$. *Occurrence.* As kieserite, also in kainite and schönite (p. 228); in sea-water and many mineral waters, to which it gives a bitter taste.

Preparation. By dissolving magnesium carbonate in dilute sulphuric acid, or by boiling kieserite for a long time with water, which gradually dissolves the same.

Properties. On evaporating its aqueous solution it is obtained as neutral, colorless, rhombic crystals having the composition $MgSO_4+7H_2O$. It has a disagreeable, bitter taste and is soluble in 1.5 parts by weight of cold water (Epsom salts).

At 70° $MgSO_4+6H_2O$ crystallizes from its saturated solution, and at 0° $MgSO_4+12H_2O$. Kieserite, $MgSO_4+H_2O$, is soluble only in 400 parts water, but it gradually dissolves on boiling with water and then crystallizes as $MgSO_4+7H_2O$.

On heating to 100° Epsom salts lose 5 molecules of water, forming $MgSO_4+2H_2O$, and at 150° they lose still another molecule, the last molecule being driven off only at 260° (water of constitution, p. 115).

With the sulphates of the alkali metals magnesium sulphate forms double salts (p. 102), which crystallize in monoclinic prisms, whereby the firmly combined molecule of water of crystallization is replaced thus:

Potassium-magnesium sulphate, $MgSO_4+K_2SO_4 \quad +6H_2O$;
Ammonium-magnesium sulphate, $MgSO_4+(NH_4)_2SO_4+6H_2O$.

The sulphates of zinc, cadmium, manganese, iron, cobalt, nickel, which are constituted similarly to the magnesium sulphate, are all isomorphous, and also, like cupric sulphate, which likewise crystallizes with 5 molecules H_2O, contain 1 molecule H_2O firmly combined. These all, like mercuric sulphate, form double salts which have an analogous composition and are isomorphous with double magnesium sulphates:

$$NiSO_4+K_2SO_4+6H_2O;\ CuSO_4+K_2SO_4+6H_2O, \text{ etc.}$$

Magnesium carbonate, $MgCO_3$, occurs as rhombohedra in magnesite (isomorphous with calcite, smithsonite, rhodochrosite, siderite, etc.), and in crystalline masses as magnesite, also in dolomite (p. 223).

If carbon dioxide is passed into water containing suspended asic magnesium carbonate (see below), we obtain from the filtered lution, on standing, neutral magnesium carbonate, $MgCO_3+3H_2O$,

the same cation, Cu'', while the cation Cu' is
lts.

a. Alloys of Copper.

cast, as on cooling it contracts irregularly and
e mould. With zinc or tin copper forms alloys
with zinc. Brass is a golden-yellow alloy of 2
part zinc. The more copper it contains the
d the more zinc the whiter is the product. Such
nchbeck or red metal, talmi-gold, Muntz metal,
-called gold foam, etc.
with tin are called bronzes. We differentiate
, bell-metal, speculum-metal, antique bronze.
nsists of copper, tin, and zinc. Copper coins
t. copper, 4 per cent. tin, and 1 per cent. zinc.
contains 0.5–0.8 per cent. P and is very hard and
ronze contains 0.5–0.8 per cent. Si, is very hard,
uctor of electricity.
r with aluminium, silver, nickel, manganese, and
of in connection with these metals.

b. Cuprous Compounds.

copper suboxide, Cu_2O, occurs as cuprite and
by heating a cupric salt solution with glucose
austic alkali. It forms a red crystalline powder
ed in the air and is insoluble in water. See also

de, $Cu(OH)$, is obtained on gently heating an alka-
ion (see below) with glucose, or by treating cuprous
alkali. It forms a yellow powder which quickly
droxide.
Cu_2S, occurs as copper glance, copper pyrites, etc.,
urning copper in sulphur vapors, as well as by heat-
the absence of air ($2CuS=Cu_2S+S$), or in a current

known only of oxygen-free acids, as Cu_2O dissolves
ming cupric salts, with the separation of metallic
$)_4=CuSO_4+H_2O+Cu$. The cuprous salts are color-
green or blue in the air, due to the absorption of

us salts are insoluble in water. Cuprous chloride
NH_3 or HCl, and both of these solutions absorb CO

nposition and isomorphous with the mag-
$K_2SO_4+6H_2O$ (p. 229).
ms the color called Casselmann's green.
mass of cupric sulphate, alum, camphor, and
, e.g.,

$_4+xNH_3$, $$Cu<\begin{matrix}NH_3Cl\\NH_3Cl\end{matrix}+xNH_3,$$

ionium salts in which 2H atoms are replaced
They contain a complex ion (p. 84) with a
d Platinum) instead of a cupric ion.
lution is treated with ammonia, a blue basic
ated. This dissolves in an excess of ammonia,
rom which deep-blue prisms of $(NH_3)_2CuSO_4+$
ed by alcohol.
150° it loses water and ammonia and a green
e, $(NH_3)_2CuSO_4$, is obtained.
forms pale-green needles with 2 mols. water,
en anhydrous. It forms double salts with alkali

AsO_3, is obtained by precipitating a cupric salt
as a beautiful green precipitate which is used
eele's green.

$CuCO_3$, is not known. If a cupric salt solu-
odium carbonate, a precipitate of the green
$3CuCO_3+3Cu(OH)_2+H_2O$ or $CuCO_3+Cu(OH)_2$,
upon the temperature and concentration of the
d forms the color Brunswick green and occurs
mineral malachite. Verdigris, patina, copper,
d by the action of air and water upon copper
ame composition. $2CuCO_3+Cu(OH)_2$ occurs
mineral azurite, which when powdered forms
nown by that name.

tection of Copper Compounds.

een or blue color to the non-luminous flame.
flame contains many lines, but the blue and
eristic.

drogen precipitates from solutions of copper
hich is insoluble in dilute acids.
pitates greenish-blue basic salts which are
bove) from copper solutions. All copper com-

xposed to the air, but the molten silver does not. The lead is
nd air is blown in by a blast; the lead is converted into oxide (litharge)
nelts and passes off, leaving finally the unoxidized silver covered
th a thin layer of lead oxide, which is finally ruptured, and the
silver remains behind.

ie lead contains only small amounts of silver, it is concentrated by
on's or Parke's process. Pattinson's process is based upon the
t a molten alloy of silver and lead solidifies slower than pure lead.
f this alloy is allowed to cool slowly, pure lead first crystallizes out,
an be removed by perforated ladles, and finally a eutectic mixture
ng 2.2 per cent. silver remains.

e's process is based from the fact that on the addition of zinc to
lead poor in silver the two metals do not mix well together, but
er leaves the lead and goes over to the zinc, forming a difficultly
lloy, which on cooling separates on the surface. The zinc is sep-
herefrom by distillation.

silver can be obtained from the crude silver by melting it with
d then driving this off, or by dissolving the crude silver in HNO_3
cipitating all the silver from solution as AgCl by means of hydro-
acid, and reducing this as described on p. 240.

silver may moreover be obtained by dissolving the crude sil-
sulphuric acid and precipitating the silver with copper or iron:
$+Fe=FeSO_4+Ag_2$; also by electrolysis, where the crude silver is
ed as the anode in a concentrated solution of silver nitrate, when
ver deposits at the cathode, which consists of a sheet of silver.

perties. White, shining, rather soft metal having a specific
of 10.5 and not oxidizing when molten, but absorbing 22 times
me of oxygen, which it gives up on cooling: this causes the
ng that takes place when fluid silver cools Ozone causes a
ial coating of silver peroxide (p. 240). Silver melts at 960°
porizes at about 2000°, forming a pale-blue vapor. Concen-
ydrochloric acid and dilute sulphuric acid do not attack silver,
concentrated sulphuric acid dissolves it, forming silver sul-
$2Ag+2H_2SO_4=Ag_2SO_4+SO_2+2H_2O$. Dilute nitric acid, even
old, dissolves silver, producing silver nitrate: $3Ag+4HNO_3=$
$+NO+2H_2O$. Silver unites directly with the halogens;
lphur it combines very readily; hence silver objects turn
hen exposed to air containing H_2S. Silver is very ductile
the best conductor of heat and electricity. Thin hammered
re called silver-foil.

r only occurs univalent, hence the designation argentous
gentic salts is not used. The silver compounds have the
mposition as the cuprous compounds.

e are also certain allotropic modifications of silver, namely, a
reen and a golden-yellow form, which are very quickly transformed

silver chloride, although not as
nia.

e, AgI, is obtained by treating a silver salt solution
dide, producing a yellowish precipitate having similar
ver chloride, but insoluble in ammonia, and is sensitive
presence of silver nitrate.

photography depends upon the fact that light causes a
of the haloid salts of silver into silver subhaloid salts,
ich by certain reducing agents (developers) are readily
er, while the unchanged haloid silver is not acted upon
er. After development of the picture, in order to make
t must be "fixed" by placing it in a solution of com-
lly sodium hyposulphite), which dissolves the undecom-
sensitive haloid silver compounds. At the present time
with silver bromide (by the aid of gelatine) are chiefly
more stable and more sensitive to light than plates covered
de and chloride. Silver iodide can be used only when wet;
loride is generally used for printing-paper.

azoate, N_3Ag, and
, $2NH_2Ag+H_2O$, silver fulminate, produced when freshly
ver oxide is treated with a concentrated solution of ammo-
de when dry with slight friction.

rate, $AgNO_3$, is prepared by dissolving silver in nitric
nd evaporating the solution. It forms colorless rhombic
h dissolve in 1 part by weight of water or 4 parts of
as a caustic action and blackens in contact with organic
kin, linen, etc.). Silver nitrate melts at 200°, and on
g it decomposes into silver nitrite, $AgNO_2$, and oxygen,
to silver, nitrogen, and oxygen.

ded when hot into sticks which are called lunar caustic,
lis. On fusion with two parts of potassium nitrate we
ed caustic.

c. Detection of Silver Compounds.

used on charcoal with soda they yield a silver globule.
er compounds with the exception of the iodide and
eadily soluble in ammonia.
hloric acid or a soluble chloride precipitates white,
er chloride from solutions of silver. This precipitate
nmonia, insoluble in acids, and darkens in the light.
zinc, iron, copper, and mercury precipitate metallic
solutions.

Hg(NO$_3$)$_2$, is obtained by dissolving m
acid (process, p. 242). It forms colorle
with large quantities of water form a
H$_2$O. It is used in the estimation
ger, as well as a reagent for proteids

Detection of Mercury Compounds.

heated in a glass tube with Na_2CO_3, a gray
mercury deposits on the cold part of the tube.
ced on metallic copper mercury deposits as a g
ecomes bright on being rubbed, and which disappea
ted hydrogen precipitates black mercuric sulphide
containing mercury. This precipitate is character-
her sulphides by being insoluble in hot nitric acid.
chloride precipitates white mercurous chloride or
ided) mercury (p. 258) from mercurial solutions.
s compounds turn black with caustic alkalies, black
(p. 244), yellowish green with potassium iodide, and
ochloric acid.
compounds become yellow with caustic alkalies,
onia (p. 246), red with potassium iodide, and are not
ydrochloric acid.

GROUP OF EARTHY METALS.

MINIUM. GALLIUM. INDIUM. THALLIUM.
ndium. Yttrium. Lanthanum. Cerium.
mium. Neodymium. Samarium. Gadolinium.
Erbium. Thulium. Ytterbium.
Dysprosium. Holmium. Philippium. Terbium.

tals occur only combined in nature and, with the excep-
allium, and cerium, exist as trivalent elements.
on of pure earthy metals is very difficult, as in their
they are extremely similar. They are especially charac-
spectrum, and many of their oxides (especially cerium
thorium, p. 263) emit an intense white light on being
luminous flame.
d their solution are partly colored, and each metal gives
bsorption spectrum.
rom the alkali and alkaline-earth metals in that their
recipitated by ammonia and that they decompose water
peratures. They are not, with the exception of indi
llium, in common with these two groups, prec
sulphides are soluble or unstable.

heat of reaction set free in its union with oxygen is used in order to temperatures up to 3000° (by the compound called thermite, which cture of powdered aluminium with iron oxide), and is also used in and melting processes, as well as in reduction processes which do e place at lower temperatures. This reduction is brought about ig to Goldschmidt's method, which consists in mixing the oxide netal to be obtained with aluminium powder, and to ignite this (reduction mass) by means of a mixture of aluminium and BaO_2 mass). By this method numerous metals which were formerly id reduced with difficulty are now obtained in a very pure and ite.

inium dissolves readily in hydrochloric acid or caustic ith the development of hydrogen: $Al+KOH+H_2O=$ 3H. It dissolves in hot sulphuric acid with the generation id it is only slowly acted upon by dilute sulphuric acid and l, as it becomes covered with a thin layer of Al_2O_3 besides . Under the air-pump receiver it dissolves readily in all he protective layer of gases is removed. On account of its nd its stability in the air it is very extensively used in the n of many useful objects.

a. *Alloys of Aluminium.*

pper alloy, aluminium bronze, is characterized by being nd stable and by its golden color.

m is an alloy with magnesium and has properties similar

n is an alloy with tungsten and is much more stable ium.

b. *Compounds of Aluminium.*

m Oxide, Alumina, Al_2O_3. *Occurrence.* In colorless, exagonal crystals it is corundum; colored red with chro- led ruby; colored blue by cobalt it is known as sapphire; h-gray crystalline masses are called emery.

n. Amorphous by heating aluminium hydroxide; y heating boron trioxide with aluminium fluoride, $=Al_2O_3+2BF_3$; also by passing chlorine over red-hot inate, $2NaAlO_2+2Cl=Al_2O_3+2NaCl+O$, as well as in s process (see above).

. Next to diamond and boron crystalline alumina is of all bodies and forms colorless hexagonal prisms. alumina is a white odorless and tasteless powder which

aluminium acetate or sodium aluminate
um, when $Al(OH)_2$ is formed.
ng solutions of aluminium hydroxide in alkali
precipitate having the composition $KAlO_2$ or
cid-forming aluminium hydrate, $HAlO_2$, corre-
diaspore, $Mg(AlO_2)_2$ as spinel, $Be(AlO_2)_2$ as
ahnite, and $Fe(AlO_2)_2$ as pleonaste.
pared on a large scale (see Aluminium Hydrox-

in water are immediately decomposed by
ium hydroxide.
l_3, is obtained by dissolving aluminium hydrox-
id evaporating. It forms white deliquescent
ich decompose on heating: $2AlCl_3+3H_2O=$
ic chlorides it forms double salts whose solu-
without decomposition: $AlCl_3+3KCl$. On a
uminium chloride can be prepared by strongly
nium oxide and carbon in chlorine gas. This
t crystalline mass: $Al_2O_3+3C+6Cl=2AlCl_3+$

F_3, occurs in cryolite (p. 248), and with $9H_2O$
ch are soluble in hot water.
l_2S_3, is obtained by heating aluminium with
low mass decomposable by water.

e, $Al_2(SO_4)_3+18H_2O$, also called concen-
lunogen, feather-alum, aluminite, websterite,
. 252).
dissolving aluminium hydroxide (obtained
auxite or cryolite, p. 250) in sulphuric acid

m-earth (aluminium silicate which contains car-
r ordinary clay (p. 252) are transformed into
means of sulphuric acid, then lixiviated with
silicic acid behind. The solution is evaporated
ly soluble iron sulphate first crystallizes out and
hate.

ium sulphate forms colorless monoclinic
masses which are readily soluble and have

inum sulphate is treated with a solution of
i metals, of ammonium, silver, or thallium,
the double salts, which crystallize in regu-
less soluble in water than the aluminium
composition $MAl(SO_4)_2+12H_2O$, where M

, Ag, Tl, or NH_4, or an organic derivative of
s are called alums and, according to the mono-
ain, are designated potassium alum, sodium
silver alum, etc.
d chromic sulphates and those of indium and
le salts with the sulphates of the monovalent
salts have the same shape and composition,
s also applied to these double salts.
omorphous double salts having the formula

re $\overset{I}{M}$ may be K, Na, Cs, Rb, Ag, Tl, or NH_4

In, Cr, In, or Ga:
$12H_2O$, Sodium iron alum.
$12H_2O$, Ammonium chromium alum.
$12H_2O$, Potassium manganese alum.

$Al(NH_4)(SO_4)_2+12H_2O$, and
um, $AlK(SO_4)_2+12H_2O$, are the most import-
s and are at the present time more and more
by aluminium sulphate or sodium aluminate
unium Hydroxide, p. 250).

alum-stone (alunite), $AlK(SO_4)_2+2Al(OH)_3$, by
ion with water, when the aluminium hydroxide
he potassium alum is obtained from the solution
allization.
om the aluminium sulphate obtained from alum
e, by treating its solution with potassium or
evaporating to crystallization.

colorless octahedral crystals soluble in 10
acid reaction to the solution, and which on
ater of crystallization, and on further heating
hydrous white porous alum (burnt alum).
n water treated with some alkali carbonate
aporation in cubes as so-called neutral or
oluble in water with neutral reaction.

s. *Occurrence.* As constituent of the most im-
th (see Aluminium, p. 248), also in the impure
n-stone, and as ordinary clay, and in the pure
olin, porcelain earth, argilla): $H_2Al_2(SiO_4)_2+$
orms immense layers and is produced by the

---

feldspathic rocks, and is a mixture of
calcium carbonate, ferric hydroxide,
of water and carbon dioxide the feld
(M=Na_2, K_2, Mg, Ca), are so decomposed
into soluble bicarbonates and the
are further decomposed into carbon
insoluble aluminium silicate remains as
$+H_2O=K_2Si_4O_9+H_2Al_2(SiO_4)_2$;
$+2H_2O+2CO_2=CaH_2(CO_3)_2+H_2A$
earth, Naples red, are natural mix
ferric oxide. Loam is a mixture of clay
is a mixture with considerable calcium

Aluminium silicates are partly
must first be decomposed (p. 19
or yellow in color and absorb wat
which shrink on heating, when their
yield sparks when struck with s
being plastic with water aft
allow water to pass through.
it is, and mixtures of clay
salts are more or less fusible
and earthenware consist of
bodies (feldspar, for exam
may be covered with a t
an impervious cov

to the purity of th
we differentiate betw
earthenware wit
Although these ar
they are still co
surface smooth and poli
(stonewar
Unglazed p
Porous earthenwa
It absorb
Faience ware
terra cotta,
(p. 220)
and is a calcin

ovalent a soluble hydroxide, sulphate, carbonate, and silicate, also use it may replace the alkali metals in the alums. On the other hand as resemblances to lead on account of its chloride and iodide, which soluble with difficulty, and its insoluble sulphide, and also on account s physical properties.

Thallium occurs only in combination, up to 17 per cent. in crookesite, to a less extent in many sulphur and copper ores, in certain brines, ecially those of Nauheim, and in sylvine and carnallite. It is obtained the electrolysis of its chloride as a very soft white metal which melts 90° and vaporizes at about 1600°, has a specific gravity of 11.8, and ich oxidizes in moist air. Thallium compounds give a beautiful green or to the colorless flame, and the spectrum of this flame consists of a gle bright-green line (θάλλος, green bud). It is precipitated from its utions by ammonium sulphide as black thallium sulphide, Tl_2S, which oluble in dilute acids.

TIN GROUP.

Tin. Germanium. Lead.
Titanium. Zirconium. Thorium.

These elements with carbon and silicon form a group (p. 185) and st as divalent and tetravalent elements.

Like silicon they form tetravalent compounds, such as volatile tetra-orides, etc., and their tetrafluorides combine with other metallic fluor-s, forming salts corresponding to and isomorphous with the silico-orides; thus potassium fluostannate, K_2SnFl_6.

On strongly heating they burn into dioxides (lead into PbO or Pb_3O_4) ich are acid anhydrides.

They decompose water only at high temperatures.

Titanium, zirconium, and thorium compounds are not precipitated n their neutral or acid solution by H_2S. Zirconium and thorium sul-ates give double salts with potassium sulphate, $Zr(SO_4)_2+K_2SO_4+2H_2O$, ich are insoluble in saturated solution of potassium sulphate.

1. Tin (Stannum).

Atomic weight 119=Sn.

Occurrence. Very seldom native, to a slight extent as SnS_2, but y widely distributed as cassiterite or tin-stone, SnO_2.

Preparation. Crushed tin-stone is purified from foreign materials means of water, roasted, and then heated with coal. The tin s obtained contains other metals and is therefore slowly heated in to fusion, when the more readily fusible tin flows off, while more infusible metals remain behind in the unmolten state.

Properties. Silver-white, soft, malleable, not tough metal hav-a specific gravity of 7.3. At 200° it becomes so brittle that it can pulverized, at 231° it melts and is covered with white tin oxide, at about 1600° it is volatile and burns, when air is supplied, into dioxide (tin-ash). It is stable in the air, hence it is used in coverroduct thus obtained, the tin salt of commerce, $SnCl_2+2H_2O$, forms olorless monoclinic crystals which become anhydrous at 100° and hich volatilize without decomposition at a red heat. $SnCl_2$ is soluble in ttle water, but when considerable water is added thereto it decomposes nd the solution becomes cloudy, due to the formation of basic stannous hloride, Sn(OH)Cl, which goes into solution again on the addition of cids. The same precipitate is obtained when the clear aqueous solution s allowed to stand in the air: $3SnCl_2+O+H_2O=2Sn(OH)Cl+SnCl_4$. This tendency to oxidize is so strong that even dry stannous chloride, on xposure to the air, is transformed into tin oxychloride, $SnOCl_2$, and hence s an energetic reducing agent. In regard to its use in the detection of rsenic see p. 177.

Stannous sulphide, SnS, is obtained by mixing a stannous salt solution with H_2S, which forms an amorphous brownish-black powder, or by melting tin with sulphur, when a bluish-gray crystalline mass is produced. It is usible, insoluble in dilute acids and alkali monosulphides. It is soluble in lkali polysulphides, forming alkali sulphostannates: $SnS+K_2S_2=K_2SnS_3$.

c. Stannic Compounds.

Stannic oxide, tin oxide, stannic anhydride, SnO_2, occurs as tintone in quadratic crystals or compact masses, seldom white, but generally olored. It is produced as fine needles by heating tin in the air, or as an amorphous white or yellowish powder by heating the two stannic acids. This powder is insoluble in water and in acids, but soluble in alkali hydrates, orming stannates (see below).

Stannic hydroxide has the formula $Sn(OH)_4$ or $SnO(OH)_2$ according o the method of drying. Both these hydroxides are known as ortho- and netastannic acids.

Orthostannic acid is produced on boiling a watery solution of stannic hloride or by treating this solution with ammonia. It forms a gelatinous precipitate which when dried forms a vitreous mass. It dissolves readily n acids, forming stannic salts, and in alkali hydrates, forming stannic acid alts or stannates; thus, Na_2SnO_3, which, on evaporation of the solution, may be obtained as crystals and from which acids precipitate orthotannic acid, which is soluble in an excess of the acid. On allowng orthostannic acid to stand under water, it is converted into metatannic acid and is then insoluble in acids. Sodium stannate, Na_2SnO_3+ H_2O, is used in cotton-printing under the name of "preparing-salt."

Metastannic acid is obtained by heating tin with concentrated nitric cid as a white powder which is insoluble in acids. With alkali hydrates forms salts, metastannates. These are insoluble in the alkali hydrates, ut, on the contrary, are soluble in pure water.

Stannic chloride, tin chloride, $SnCl_4$, is obtained on heating tin or annous chloride in chlorine gas. It is a colorless, fuming liquid which oils at 114°. With a little water it solidifies to a soft crystalline mass, nCl_4+xH_2O (butter of tin); with more water it dissolves completely; n boiling the solution insoluble metastannic acid separates out: $SnCl_4+$ $H_2O=H_2SnO_3+4HCl$. The definite crystalline double salt, $SnCl_4+$ NH_4Cl, serves in cotton-printing as "pink salt."

Stannic sulphide, tin sulphide, SnS_2, is obtained by treating a stannic lt solution with sulphuretted hydrogen. It forms an amorphous yellow owder which is insoluble in dilute acids. At a red heat it decomposes

3. Lead (Plumbum).

Atomic weight 206.9 = Pb.

e. Very seldom native, but widely distributed as
seldom as cerussite, $PbCO_3$, wulfenite, $PbMoO_4$, crocoite,
morphite, $Pb_3(PO_4)_2 \cdot PbCl_2$, anglesite, $PbSO_4$, bournonite,
(p. 181).

ı. Nearly entirely from galena by the following methods:
so-called precipitation method, where the lead sulphide is
rap-iron: $PbS + Fe = Pb + FeS$.
roasting process. Lead sulphide is roasted, whereby lead
l sulphate are produced: $PbS + 3O = PbO + SO_2$; $PbS +$
'he supply of air is then shut off, when the oxidized com-
sformed into lead by the unchanged lead sulphide present:
$Pb + SO_2$; $PbS + PbSO_4 = 2Pb + 2SO_2$.
ill contains foreign metals. The silver contained therein
ording to the method described (p. 238). If this is done
on process, then the lead is transformed into lead oxide,
l again by means of carbon.

Bluish-gray shining metal, very soft and ductile,
11.4. It leaves a mark on paper; melts at 335°, and
l with a gray scum called lead-ash ($Pb_2O + PbO$); at
zes, and burns into lead oxide on the supply of air. It
y in nitric acid. When compact it is not attacked
hydrochloric acid, as the lead sulphate or lead chloride
count of its insolubility, protects the lead from
In the presence of air it is even attacked by weak
for instance acetic acid; hence it must not be used
tensils. In dry air it remains unchanged, while in
s covered with a thin layer of PbO. It decomposes
white heat; with water containing air it forms in the
ontrary, lead hydroxide, which is somewhat soluble in

ı of air and water on lead is of importance, as lead pipes are
onveyance of water, and lead salts are poisonous. Ordinary
in behavior towards lead according to the salts contained
e lead is more readily dissolved when chlorides and nitrates
but if, on the contrary, the water is hard, containing car-
sulphates, then the insoluble coating of lead sulphate or lead
hich forms in the lead pipes protects the metal from further
hat the water that flows through is unaffected. Chemically
does not form any protective coating.

ccurs divalent as plumbous compounds and tetravalent as
ompounds. Most plumbous compounds are isomorphous

the chief constituent of flint and crystal gl
earthenware (p. 253).

, PbS, occurs as galena in regular crystals having
also p. 262, 3).

ate, lead carbonate, $PbCO_3$, occurs naturally as cerus-
with aragonite, etc. (p. 223). It is obtained as a
cipitating a plumbous salt solution with ammonium

ous Carbonate. If a plumbous salt solution is treated
ali carbonates, white basic plumbous carbonate,
on changes with the temperature and concentration
, precipitates out. This may be represented by
$CO_3+Pb(OH)_2$, where $n=2, 3, 4$, etc. A carbonate
ula $2PbCO_3+Pb(OH)_2$ is the pigment called *white*
epared by the action of carbon dioxide upon basic
cording to various methods.

ethod. Carbon dioxide is passed into a solution of basic
lution of lead oxide in lead acetate), whereby the neutral
oduced remains in solution, while the white lead precipi-
tral lead acetate is again transformed into the basic salt
ad oxide therein.

Method. Lead oxide and lead acetate are rubbed with
on dioxide passed through. The basic lead acetate here
nposed as described in method 1.

ethod. Rolled sheets of lead are placed in pots contain-
r, and these surrounded by manure. By the fermentation
erature takes place. The vinegar evaporates and forms
ate with the aid of the oxygen of the air. This is con-
ite lead and lead acetate by the carbon dioxide produced
tion of the manure.

c. *Plumbic Compounds.*

ide, lead peroxide, PbO_2, may be considered as the anhy-
o- and metaplumbic acids; e.g., $PbO_2+2H_2O=H_4PbO_4$;
H_2PbO_3 (see below). It is formed at the positive pole in
accumulators from the lead sulphate covering the lead.

It is also produced on treating minium, $2PbO+PbO_2$, or
tric acid, when the PbO dissolves, forming lead nitrate, while
nains as an insoluble dark-brown amorphous powder:
$_3=PbO_2+2Pb(NO_3)_2+2H_2O$. If reducing bodies, such as
id, etc., be added at the same time, then the PbO_2 is reduced
en dissolves in nitric acid.

lead peroxide decomposes into PbO and O; warmed with
cid it forms lead chloride with the development of chlorine,
huric acid it forms lead sulphate with the generation of

$$PbO_2+H_2SO_4=PbSO_4+H_2O+O;$$
$$PbO_2+4HCl=PbCl_2+2H_2O+2Cl.$$

romous Compounds.

they have great power of absorbing oxgyen
omic salts.
ot known.
$(OH)_2$, is obtained by treating chromous
which gives a yellow precipitate that is
mic oxide with the evolution of hydrogen:
$H)_2 = Cr_2O_3 + H_2O + 2H$.
is obtained by passing hydrogen over heated
s a white crystalline powder forming a blue
lution takes up oxygen with activity and be-
e formation of Cr_2OCl_4(?).

hromic Compounds.

gously to the corresponding aluminium com-
n sesquioxide, Cr_2O_3, an amorphous green
ds, is produced on heating $Cr(OH)_3$ or CrO_3.
crystals isomorphous with Al_2O_3 and Fe_2O_3,
myl chloride through a red-hot tube:
$l_2 = Cr_2O + 4Cl + O$.
$H)_3$, is precipitated from chromic salt solu-
nmonia as a bluish-gray precipitate which,
eak acid and is soluble in an excess of caustic
ng again on boiling. On the other hand it
$OH)_3$ and $Fe(OH)_3$, but not combining with
c acid, sulphurous acid, sulphuretted hydro-
a current of hydrogen it is converted into
O_2 or $CrO(OH)$, which is bluish gray and
ic acid. The hydrate $Cr_2O(OH)_4$ is used as
Guignet s green.
ds corresponding to the aluminates (p. 251)
e.g., $Mg(CrO_2)_2$.
d by dissolving chromic hydroxide in the
ting at as low a temperature as possible.
oducing a violet solution in cold water; on
come green and on evaporation yield amor-
nsist of a mixture of basic and acid chromic
lissolved, then the solution gradually becomes
ration violet crystals of the neutral chromic

phate, chrome alum, $KCr(SO_4)_2 + 12H_2O$ (p.
edra and is obtained by the action of sulphur
potassium dichromate treated with sulphuric
ame: $K_2Cr_2O_7 + H_2SO_4 + 3SO_2 = 2KCr(SO_4)_2 +$

Divalent they form compounds which are similar to those of the sium group, as well as to the cupric compounds, especially by the ior of their sulphates and their carbonates.

Trivalent they form compounds which are constituted analogously se of the aluminium and chromium groups.

Manganese and iron also occur hexavalent, producing acids; man- also tetravalent and heptavalent.

ie six elements of the platinum group as mentioned on p. 55 are to the metals of the iron group with regard to chemical properties ieir position in the periodic system.

1. Manganese.

Atomic weight 55=Mn.

ccurrence. Only native in meteorites; combined as pyrolusite rownstone (MnO_2), braunite (Mn_2O_3), manganite, ($MnO.OH$), mannite (Mn_3O_4), rhodochrosite ($MnCO_3$), alabandite (MnS). es of manganese are found in many plants and animals.

Preparation. By fusing manganese oxides with carbon or with ninium (p. 248).

Properties. Grayish-white, very hard, brittle metal of specific ity 7.5, melting at about 1900°. It oxidizes in moist air, decom- s boiling water with the generation of hydrogen, dissolves in cids, forming manganous salts, is not, unlike the other metals of group, attracted to a magnet, nor does it become magnetic.

Divalent manganese forms the manganous compounds, triva- manganese the manganic compounds, the hexavalent manga- the manganic acid compounds, and heptavalent manganese the anganic compounds.

a. Alloys of Manganese.

upro-manganese, manganese copper (30 per cent. Mn), is a constituent rious alloys of copper having great hardness and toughness (manga- bronzes); spiegel-eisen (10 to 20 per cent. Mn) and ferro-manganese o 70 per cent. Mn) are of importance, as they make varieties of iron r and tougher. Manganin, see Nickel.

b. Manganous Compounds.

anganese monoxide, manganous oxide, MnO, is obtained by heating anous carbonate in the absence of air, or by heating all oxides of anese in a current of hydrogen. It is a green powder readily solu- acids, and quickly oxidizes into brown manganous-manganic oxide, $_4$, in the air.

anganous hydroxide, $Mn(OH)_2$, is obtained by treating a manganous olution with caustic alkali, when a white precipitate is formed quickly oxidizes in the air into brown manganic hydroxide.

nganous sulphide, MnS, occurs as manganese blende (alabandite) ck cubes, and is obtained by treating a manganous salt solution with

$)_2$ is soluble in 4 parts water
has a greater oxidizing and disin-
an $KMnO_4$.

e. *Detection of Manganese Compounds.*

sed with borax in the outer blowpipe flame they
yst-red bead.
eated with soda and saltpeter they give a bluish-green
n manganate.
ium sulphide precipitates flesh-colored manganous
o from manganates and permanganates):
$nO_4+4(NH_4)_2S=K_2S+MnS+4H_2O+2S+8NH_3$.

2. Iron (Ferrum).

Atomic weight 55.9=Fe.

ce. Native only in meteoric iron, but combined in small
n river-, sea-, and spring-waters, and in large quantities in
rals which often form extensive deposits:
rric oxide, Fe_3O_4, as magnetic iron ore.
xide, Fe_2O_3, as red hæmatite, specular iron ore; blood-
n clay as red clay-ironstone and called itabiryte.
xide and hydroxide, $Fe_2O_3+2Fe(OH)_3$, as brown hæmatite
.
sulphide, FeS_2, when regular as iron pyrites and when
lled marcasite.
rric sulphide, $5FeS+Fe_2O_3$, as magnetic pyrites.
carbonate, $FeCO_3$, as spathic iron ore.
and ferric silicates occur in many minerals and in most
each the soil after weathering. Iron nitride is found

ion. Pure iron is not obtained by the reduction of iron
carbon, as this latter forms in part a carbide with the
obtained by heating ferric oxide or ferrous chloride in a
drogen which forms a gray powder that inflames spon-
the air and burns into ferric oxide (iron pyrophorous).
ion takes place at higher temperatures, it is no longer
reduced iron, ferrum reductum). It is obtained in com-
y fusing powdered iron in the oxyhydrogen blowpipe
he purest wrought iron (piano-wire) with iron oxide,
oxide takes up all the impurities.

and allowed to crystallize. On roasting the of the sulphur is eliminated as sulphur dioxide anufacture of sulphuric acid. Ferrous sulphate the obtainment of copper by the wet method ble in 1.8 parts cold water, insoluble in alcohol, and r it is transformed into ferric oxide (p. 130).

hates it forms isomorphous double salts corresponding ompounds, of which iron ammonium sulphate, $FeSO_4+$ so-called Mohr's salt, is characterized by its stability nagnesium sulphate, ferrous sulphate loses its seventh first at 260°.

te (siccum), $2FeSO_4+3H_2O$, is obtained as a white powder s sulphate until it has lost 35 per cent. of its water and per cent.

sphate, $Fe_3(PO_4)_2$, occurs with $8H_2O$ as vivianite, is ob- te precipitate, which is insoluble in acetic acid, but soluble by treating ferrous salt solutions with sodium phosphate. n the air and becomes grayish blue.

rbonate, $FeCO_3$, occurs as spathic iron ore in yellowish crys- or in rhombohedra (which are isomorphous with carbonates nagnesium, zinc, manganese, as well as with nickelous and rbonates). It is obtained by treating a solution of ferrous kali carbonate with the exclusion of air. It is a white pre- ich in the air is quickly changed into brown ferric hydroxide; ition of sugar retards the oxidation for a long time, a mixture carbonate with sugar forms the official Ferri carbonas sac-

Ferrous carbonate is somewhat soluble in water containing ioxide and occurs in what are called chalybeate waters.

c. Ferric Compounds.

rric oxide, Fe_2O_3, occurs extensively in nature (p. 277). It is ned as an amorphous reddish-brown powder, difficultly soluble in , by heating green vitriol (in the manufacture of fuming sul- ric acid, p. 130), also from ferrous or ferric hydroxides.

Ferric hydroxide, $Fe(OH)_3$, occurs as brown hæmatite (p. 277), is produced as rust on exposing iron to moist air. It is ob- ned by mixing a ferric salt solution with an excess of caustic alkali ammonia carbonate (p. 284) which gives a reddish-brown precipi- te insoluble in water and readily soluble in acids. It may be dried y careful heating, forming an amorphous granular mass. When eshly precipitated it serves as an antidote in arsenical poisoning p. 174).

With cane-sugar, $C_{12}H_{22}O_{11}$, it forms a so-called iron **saccharate**, $2Fe(OH)_3+C_{12}H_{22}O_{11}+7H_2O$, which is readily soluble in water.

Detection of Iron Compounds.

sulphide precipitates black ferrous sulphide
iron salts. This precipitate is readily soluble in

rrocyanide produces with ferrous salt solutions
which quickly changes to light blue. In ferric
immediately produces a deep-blue precipitate of
Cyanogen Compounds).
ferricyanide produces immediately a deep-blue
Turnbull's blue with ferrous salts. With ferric
a reddish-brown coloration.
(which see) produces no change in ferrous salt
h ferric salts it immediately gives a bluish-black
nt of common ink).
sulphocyanide (which see) produces no change
, but with ferric salts it gives a blood-red colora-
n sulphocyanide, $Fe(CNS)_3$.

3. Cobalt.

Atomic weight 59=Co.

Native only in meteoric iron; combined as safflorite,
, CoS.As, cobalt pyrites or linnæite, $CoS+Co_2S_3$,
erythrite, $Co_3(AsO_4)_2$.

In all cobalt ores cobalt is in part replaced by isomor-
n. The separation of these metals takes place in a similar
uantitative analysis. We obtain finally by this method
, which is mixed with flour into a dough, this pressed
s, dried, and heated to a white heat in large crucibles sur-
arcoal powder (cube cobalt of commerce).

. Reddish-white, ductile, tough, shining metal having
vity of 8.9, melting at about 1800°; it is attracted to
d, like iron, is temporarily magnetic and passive (p. 278).
change in moist air; decomposes water at a red heat;
owly in hydrochloric or sulphuric acid, but rapidly in
forming the corresponding cobaltous salts and H or NO
y.
alent it forms the cobaltous compounds; these behave sim-
magnesium compounds (p. 229) and are very stable. The
his series are mostly red when they contain water, and blue

obaltic-hydrocyanic acid, $H_3Co(CN)_6$ (known free), and of
acid, $H_3Co(NO_2)_6$ (not known free), are also known. The
of the latter, potassium cobaltic nitrite, $K_3Co(NO_2)_6$, which
yellow precipitate when a cobaltous salt solution is treated
d and potassium nitrite, is used in the separation of cobalt
l in the detection of potassium, and forms the color called

compounds have complex ions instead of one cobalt ion,
ot give the following reactions for cobalt.

c. Detection of Cobalt Compounds.

sed with borax they yield a beautiful blue vitreous mass.
um sulphide precipitates black cobaltous sulphide, which is
ute hydrochloric acid (all other metals, with the exception
h are precipitable by ammonium sulphide form sulphides
ole in dilute hydrochloric acid).
m nitrite precipitates yellow potassium cobaltic nitrite
salt solutions acidified with acetic acid (see above).
lkali precipitates blue basic cobaltous salts (p. 286).
a precipitates blue basic cobaltous salts, which are soluble
nmonia with brown coloration, gradually becoming red;
salts are hereby produced.

4. Nickel.

Atomic weight 58.7=Ni.

Native only in meteoric iron; combined as copper-
lite, NiAs, nickel glance or gersdorffite, NiAsS, nickel
nd garnierite, $Ni_5Si_4O_{13}+Mg_3Si_4O_{13}+3H_2O$ and also in the

. Since the discovery of garnierite, nickel is nearly entirely
this mineral by means of the blast-furnace, in the same way
l other nickel ores the nickel is partly replaced by isomor-
Cu; the separation of these metals takes place in several
ys; the nickel oxide finally obtained is reduced similarly to
le (see Cobalt).

. Silver-white, ductile, tough metal, of specific gravity
able in the air, decomposing water at a red heat, melting
0°, slowly dissolved by hydrochloric and sulphuric acids,
y nitric acid with the evolution of H or NO. It is attracted
and may, like iron, be temporarily magnetic as well as
account of its silver-like color and stability, it is exten-
to cover other metals (nickel plate). Like iron, it com-
arbon monoxide (p. 189). Nickel compounds correspond
titution and properties to those of cobalt, and are obtained
manner.

; the higher oxides, with the excep-
oxides. Gold occurs mono- and tri-

rm the platinum group. They are
l with each other in the platinum
iron group, and those arranged in
reat chemical similarity:

Cobalt.	Nickel.
Rhodium.	Palladium.
Iridium.	Platinum

cur di-, tri-, tetra-, and octavalent,
vhen hexavalent salts corresponding
nganese and ruthenium also occur
l $HRuO_4$. Osmium and ruthenium

occur di-, tri-, and tetravalent, and
ivalent stable salts corresponding to
. They also form complex amine

cur di- and tetravalent, nickel also
orm amine salts with NH_3.
well as gold, form, as cyanides, com-
s, and also as chlorides with alkali

avity of 11.8 to 12.1, are called the
t, having a specific gravity of 21.1 to
etals.

urum).

t 197.2 = Au.

vith silver in the crystalline rocks
eathering of the same. Nearly all
of gold.
ocks containing gold are stamped,
all lighter particles are removed,
shing). The sands may also be
it forms an amalgam, and the
ved gold by distillation.
fter the amalgamation process, are
assium cyanide with an excess of air,
as potassium aurocyanide, $KAu(CN)_2$
n the solution by the galvanic current
ore can also be treated with chlorine,
ipitated by ferrous sulphate (process,

ted from the silver, which is nearly
ith nitric acid (p. 160), or with con-
es the gold undissolved.

and forms a [illegible] posing on heating auric chl
ing, and into $AuCl_3$ + [illegible] on boiling with water. into Au+Cl upon

c. *Auric Compounds.*

Auric oxide, auric anhydride, gold oxide, Au_2O_3, is produced
nesium aurate by treatment with concentrated nitric acid: M
$2HNO_3 = Mg(NO_3)_2 + H_2O + Au_2O_3$. It is a brown powder whi
like auric hydroxide and decomposes at 250° into $Au_2 + O$.

Auric hydroxide, auric acid, $Au(OH)_3$, is prepared from m
aurate (see below) by treatment with dilute nitric acid, Mg
$2HNO_3 + 2H_2O = Mg(NO_3)_2 + 2Au(OH)_3$, giving a reddish-brown
which decomposes in the light, with the generation of oxygen.
solves in hydrochloric acid, forming auric chloride; it is not att
oxyacids, and dissolves in alkali hydroxides, forming aurates.

The *aurates* are derived from metauric acid, $HAuO_2$, which is no
free. If an auric chloride solution is gently warmed with mag
oxide, we obtain a yellow precipitate of magnesium aurate, Mg(
if auric chloride solution is treated with caustic potash, auric hyd
is precipitated, and this dissolves in an excess of the caustic potash, fo
potassium aurate, $KAuO_2$, which on careful evaporation may be ob
as yellow needles: $Au(OH)_3 + KOH = KAuO_2 + 2H_2O$.

Auric chloride, $AuCl_3$, so-called brown gold chloride, is obtained
brown crystalline, deliquescent mass on heating powdered gold in
rine gas. If heated to 1[illegible]0°, it decomposes into $AuCl + Cl_2$, and
slowly evaporating its watery solution it separates in yellow needles
$AuCl_3 + 4H_2O$.

Hydrochlorauric acid, $HAuCl_4$, so-called yellow gold chloride, se
rates with four molecules of water in yellow crystals on the evaporati
of the solution obtained by dissolving gold in aqua regia.

Chloroaurates are prepared by evaporating the mixed solutions
auric chloride and the respective metallic chloride. They form yello
crystals, e.g., sodium chloroaurate, $NaAuCl_4$ (gold salt of the photog
rapher).

Gold oxide ammonia, $Au_2O_3 + 4NH_3$, is obtained as a yellowish-brown,
readily explosive precipitate when a gold chloride solution is treated with
ammonia.

Auric sulphide, gold sulphide, Au_2S_3, is obtained as a black precipitate
from gold salt solutions by sulphuretted hydrogen; it is only soluble in
aqua regia, and in alkali sulphides it dissolves, forming sulphoauric salts
(p. 176), which are derived from sulphoauric acid, H_3AuS_3, which is not
known free.

d. *Detection of Gold Compounds.*

1. When fused with soda upon charcoal they yield golden ductile granules.

2. Zinc, iron, copper, and many other metals, also reducing agents, such as ferrous sulphate, arsenic trioxide, sulphur dioxide, oxalic acid, etc., precipitate metallic gold as a brown powder from gold solutions. On rubbing this powder with a hard object it takes a metallic luster.

3. Sulphuretted hydrogen precipitates black auric sulphide, readily soluble in yellow ammonium sulphide, forming $(NH_4)_3AuS_3$.

Platinum occurs divalent in the platinous compounds and tetravalent the platinic compounds.

a. Alloys of Platinum.

Platinum alloyed with 2 to 3 per cent. iridium is ordinarily used, it is harder and more resistant to chemicals.

b. Platinous Compounds.

Platinous oxide, PtO, is obtained as a gray powder on carefully heat-ng $Pt(OH)_2$.

Platinous hydroxide, $Pt(OH)_2$, is obtained as a black powder on arming $PtCl_2$ with caustic alkali. Both of these compounds dissolve in ases and acids with the formation of salts.

Platinous chloride, $PtCl_2$, produced on heating hydrochlorplatinic cid to 280°, is a green powder, insoluble in water, which readily forms oluble double salts with the alkali chlorides, Na_2PtCl_4, which are derived rom

Hydrochlorplatinous acid, H_2PtCl_4, which is obtained on evaporating tCl_2 with HCl. It forms yellow crystals.

Platosamines is the name given to the compounds of platinous salts ith ammonia; e.g., $PtCl_2(NH_3)$, $PtCl_2(NH_3)_x$, $Pt_2Cl_2(NH_3)$, etc., in which, place of one platinum ion, a complex ion with one or two divalent plati-um atoms exists (p. 84).

c. Platinic Compounds.

Platinic oxide, PtO_2, produced as a black powder on heating $Pt(OH)_4$, d behaves like this towards acids and bases.

Platinic hydroxide, $Pt(OH)_4$, platinic acid, precipitates as a reddish-own powder by treating a solution of platinic chloride with caustic kali. It dissolves in an excess of caustic alkali, forming potassium plat-ate; e.g., $Pt(OH)_4 + 4KOH = K_4PtO_4 + 4H_2O$. It dissolves in acids, rming the corresponding platinic salts; e.g., $Pt(SO_4)_2$.

Platinates are also produced on fusing platinum with alkali hydroxides.

Platinic chloride, $PtCl_4$, is produced by the action of chlorine upon latinum at very high temperatures and hence is better obtained by heating H_2PtCl_6 in a current of chlorine. It forms reddish-brown crystalline asses which readily dissolve by water. On the evaporation of its watery olution $PtCl_4 + 5H_2O$ separates in yellow prisms.

Hydrochlorplatinic acid, $H_2PtCl_6 + 6H_2O$, platinum chloride of com-merce, is obtained as red, deliquescent crystals by evaporating a solution of platinum in aqua regia.

Chloroplatinates. Those of potassium, ammonium, calcium, rubidium, s well as numerous organic bases, are difficultly soluble in water, hence H_2PtCl_6 is used in chemical analysis.

Platinic sulphide, PtS_2, is obtained as a black precipitate, insoluble in all acids, with the exception of aqua regia, by passing H_2S into platinic salt solutions; alkali sulphides dissolve it slowly with the formation of sulphoplatinic salts (p. 176), which are derived from

Sulphoplatinic acids, $H_4Pt_3S_6$ and H_2PtS_6, which can be separated from the corresponding sulpho salts.

Platinamines are the compounds of platinic salts with ammonia, e.g.,

$PtCl_4(NH_3)$, $PtCl_4(NH_3)_x$, etc., and which have a constitution analogo to that of the cobaltic-amine salts (p. 286).

d. Detection of Platinum Compounds.

1. When fused with soda on charcoal they yield gray porous platinu (spongy platinum) without incrustation.

2. Sulphuretted hydrogen precipitates black platinic or platinous s phide from its solution. On the addition of ammonium chloride or pota sium chloride to its solution in aqua regia, the corresponding hydrochlo platinic acid salt is precipitated (p. 208), or finely divided platinum precipitated from its solutions by metallic zinc.

3. Palladium.

Atomic weight 106.5=Pd.

This metal occurs only native and in the platinum ores (preparatio p. 292). It is white, has a specific gravity of 11.9, and melts at abou 1500°; when finely divided as so-called palladium black it dissolves o boiling with concentrated hydrochloric acid, sulphuric acid, or nitric acid It has the property, especially when finely divided, of absorbing hydrogen even 980 times its volume, with the formation of a solid solution (p. 65 which appears like palladium and has an energetic reducing power lik nascent hydrogen. Palladium occurs divalent in the stable palladou compounds and tetravalent in the less stable palladic compounds; e.g. $PdCl_4$.

Compounds of Palladium.

Palladous iodide, PdI_2, is precipitated from solutions of iodides b palladium salts as a black powder, and is used in the quantitative estima tion of iodine in the presence of chlorine and bromine.

Palladous chloride, $PdCl_2$, forms brown masses.

Palladic chloride, $PdCl_4$, is known only in solution; from both of the alkali chlorides precipitate the salts of hydrochlorpalladous acid, H_2PdC and hydrochlorpalladic acid, H_2PdCl_6, which are not known free.

4. Iridium.

Atomic weight 193=Ir.

5. Rhodium.

Atomic weight 103=Rh.

6. Ruthenium.

Atomic weight 101.7=Ru.

These metals occur only native in the platinum ores (preparation, 292), are insoluble when pure in acids and aqua regia, but when alloy with platinum are partly soluble. $IrCl_3$, $RhCl_3$, $RuCl_3$, are formed heating the respective metal in a current of chlorine; these give cry talline, rather soluble complex salts with 2 mols. of alkali chloride K_2RuCl_5, Na_2IrCl_5, $(NH_4)_2RhCl_5$. On dissolving Ru and Ir in aqua re $RuCl_4$ and $IrCl_4$ are formed, which with 2 mols. of alkali chlorides yi rather soluble compounds which are isomorphous with the correspondi platinum salts; e.g., K_2RuCl_6, $(NH_4)_2IrCl_6$. $RhCl_2$ and $RhCl_4$ are known; on the other hand $RhCl_3$ is found.

Iridium is light gray, ductile, has a specific gravity of 22.4, and me at 1950°. Its name is derived from the various colors of its compound

Rhodium is light gray, ductile, has a specific gravity of 12.1 and me at about 1860°. Its name is derived from its red double chlorides (ῥοδό rose-red).

PART THIRD.

CHEMISTRY, OR CHEMISTRY OF THE CARBON COMPOUNDS.

CONSTITUTION.

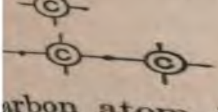
umber of known carbon compounds is much greater than pounds of all the other elements together, and new organic nds are being continually prepared artificially.

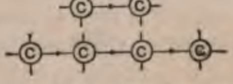
number of atoms which form the molecule of an organic und is as a rule very much larger than in inorganic compounds; for example, cane-sugar, $C_{12}H_{22}O_{11}$, contains 45 atoms and n, $C_3H_5(C_{18}H_{35}O_2)_3$, 173 atoms.

his multiplicity and complexity of organic compounds can be ained (see Isomerism, p. 300) by the fact that the C atoms are avalent and have the power of uniting with each other by means one of the bonds to a much higher degree than the atoms of any ner element. This bondage can also take place in a great many fferent ways.

Carbon is a tetravalent element and exists in its simplest compound (with the exception of CO) with all four valences satisfied, e.g., $C\overset{I}{H}_4$, $C\overset{II}{O}_2$, $C\overset{II}{S}_2$; these four bonds (affinities, valences, p. 28) of carbon are alike in behavior.

When tetravalent carbon atoms combine together, then in th simplest case one bond of one atom saturates one bond of the oth atom. Thus if two carbon atoms combine in this way, then two the eight bonds are necessary for the union of the C atoms; if t atoms combine, then four of the twelve valences are nece on; if four carbon atoms combine, then six bonds he mutual union, etc. Thus:





arbon atom introduced therefore contains only two which other atoms or groups of atoms, depending lence, can be united. If we consider these valences nstance, with hydrogen, then we obtain the compounds ${}_3H_8$, C_4H_{10}, etc., or CH_4, $H_3C{-}CH_3$, $H_3C{-}CH_2{-}CH_3$, $H_2{-}CH_3$, etc. Each of these hydrocarbons (as well vatives) differs from the previous one by CH_2 and hence we nt this series by the general formula C_NH_{2N+2}, where N can ach full number; e.g., $C_{30}H_{62}$.

of these combinations can take up more atoms or groups than are represented by the formula C_NH_{2N+2}, because the g valences of the C atoms are necessary for the mutual ence all combinations which contain C atoms which are united r with one bond each, are called saturated compounds.

ides saturated compounds we know of others which contain ns united together by more than one valence. The individual carbons of these series (as well as their derivatives) differ also one another by CH_2; e.g.,

$CH_2{=}CH_2$. $CH_2{=}CH{-}CH_3$. $CH_2{=}CH{-}CH_2{-}CH_3$.

$CH{\equiv}CH$. $CH{\equiv}C{-}CH_3$. $CH{\equiv}C{-}CH_2{-}CH_3$.

he compounds C_2H_4, C_3H_6, C_4H_8, etc., correspond to the general ula C_NH_{2N}, the compounds C_2H_2, C_3H_4, C_4H_6, etc., to the general nual C_NH_{2N-2}, where N represents a full number from 2 on.

The union of the C atoms by several bonds does not denote rmer mutual union of these atoms, as such combinations are in fact ich more readily split than those where the C atoms are simply ited.

Compounds with multiple-united C atoms can be converted into mpounds having the C atoms in simple union; thus the compounds aving the formula C_NH_{2N} and C_NH_{2N-2} can be converted into compounds having the formula C_NH_{2N+2} by the action of hydrogen. In hese cases the C atoms with double and treble bonds are changed o simple bonds.

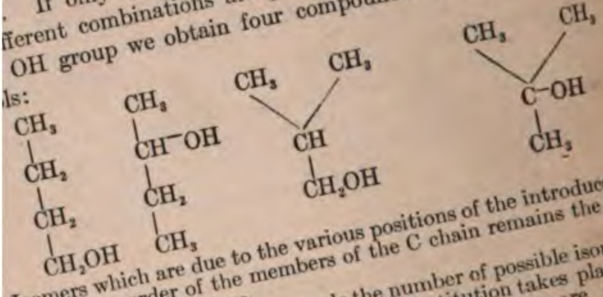
naving continuous carbon chains without branches are *rocarbons.*
depend upon differing arrangement of the C chain are *somers.*
obtain isomeric combinations by the introduction of
H_3 group in different positions, so we can obtain the
ntroduction of other atoms or groups of atoms. In
ke CH_3Cl, CH_2Cl_2, $CHCl_3$, only one formation is possible
omerism), also in CH_2Cl-CH_3. In compounds like
$(OH)_2$, etc., two arrangements of the atoms are possible,

CH_2Cl-CH_2Cl.
CH_3-CHCl_2
$CH_2(OH)-CH_2(OH)$.
$CH_3CH(OH)_2$

next hydrocarbon, $CH_3-CH_2-CH_3$, two different com-
e possible by the substitution of a chlorine atom, namely,

$CH_3-CH_2-CH_2Cl$
$CH_3-CHCl-CH_3$.

bove stated, two compounds having the formula C_4H_{10} are
. If only one H atom is substituted in these compounds,
fferent combinations are possible; thus, on the introduction
OH group we obtain four compounds C_4H_9OH, called butyl
ls:



Isomers which are due to the various positions of the introduced atoms,
c., while the order of the members of the C chain remains the same, are
lso called *position isomers.*

With the unsaturated compounds the number of possible isomers is still
reater than with the saturated because substitution takes place at differ-
ent points and also because the bonds of the C atoms are multiple at
certain points.

In regard to the special form of isomerism which occurs with
compounds with ring-formed C atoms, we refer to isocarbocyclic
and heterocyclic compounds.

3.) **Stereoisomerism.**

having similar qualitative and percentage
or which differ in only a

---

in their chemical properties, but wh
in their ~~physical~~ properties (for ex
towards polarized light) and which
isomeric (also *optically isomeric*) comp
kind of physical isomerism is due to a
of the molecules themselves, since it
thus, for example, the crystal
in two or more crystal form
p. 35), and further the property
diverting the ray of polarized l
this property is not retained whe
dissolved state, namely, whe
one another (p. 38).
second kind of physical isome
of the atoms in the m
certain isomeric compounds
polarized ray of light eq
they are in the m
molecules are free
This kind of
of certain unsatu
other in all their

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emical properties, but which exhibit certain ~~sical~~ properties (for example, variation in ized light) and which are therefore called optically isomeric) compounds. isomerism is due to a varied arrangement or les themselves, since it appears only in solid example, the crystallization of one and the , or more crystal forms (dimorphism and poly- further the property possessed by certain sub- he ray of polarized light only when in the solid y is not retained when the substances are in the state, namely, when the molecules are free to other (p. 38).

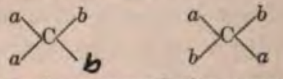
of physical isomerism can be caused only by the atoms in the molecules, and is exhibited in the eric compounds which have the power of diverting ay of light equally strongly to the right or to the e in the melted or dissolved condition, namely, es are free to move about one another (optical kind of physical isomerism is also exhibited in ain unsaturated isomeric compounds which differ in all their physical and in certain of their chemical

sort of physical isomerism cannot be explained of structure or constitution (p. 30), since it is not these how a difference in the structure of the given ounds can be possible, but it can be explained if the gement of the atoms in the molecule is taken into consideration.

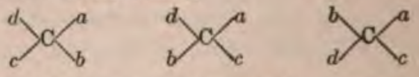
compounds whose isomerism can only be explained on ption of a different spatial arrangement of the atoms in ule are called *stereoisomeric* (*στερεόν*, solid body) and, this m is called *stereo-* or *space-isomerism*, also *allo-* or *geometric* sm. The formulas representing these compounds are called *hemical formulas*, and instead of speaking of the structure or itution of such bodies the expression “configuration of the cules” is employed.

The structural or constitutional formulas represent the bonding together of the carbon atoms and the distribution of the atoms and radicals combined with them in such a manner that the formula always lies in a single plane; but since all bodies, including molecules, must extend in three dimensions, this is not expressed in the original formulas; indeed these are actually contradictory to many facts.

For example, by assuming that the four valences of carbon all lie in one plane, of all compounds of the formula Ca_2b_2 (where *a* and *b* represent different monovalent groups*), there would be two isomers possible, namely, one where *a* and *a* and *b* and *b* were adjoining, and one where they were separated from each other:



while in fact only one such compound (for example, only one methylene chloride, CH_2Cl_2) is known and nothing points to the existence of two such isomers. Of all compounds having the formula *Cabcd* there must exist for each three isomers, namely,



while actually only two isomers are known, for example, two chlorbromiodomethanes, CHClBrI.

When a spatial configuration is assumed for the carbon compounds, in accordance with the theory proposed by Le Bel and van't Hoff all of the previously mentioned difficulties and contradictions disappear.

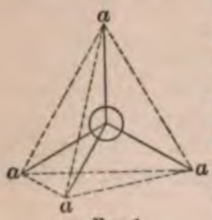


FIG. 1.

This theory is based on the assumption that the four valences of every carbon atom are equally distributed symmetrically about the space surrounding the carbon atom, and that the direction of every valence forms the same angle with the direction of every other valence, which agrees with the equal value of each of the four valences. This is best represented by placing the carbon atom at the center of a tetrahedron, the four valences being directed towards the four solid angles of the tetrahedron.

If we imagine that in the molecule of the compound *Caaaa* three the similar groups *a* are replaced by dissimilar groups, then the followi isomers are possible:

a) Isomers in the case of simple saturated compounds.

a. If a group *b* or still another group *c* takes the place of one two of the groups *a*, then only one configuration can be concei since both figures can be made to correspond by turning, so that immaterial on which angle of the tetrahedron the substitution takes and 3). Therefore mono- and disubstitution products of methane st only in one modification, a fact justified by experience.

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* The expression "group" as used in this chapter denotes "an atom or an group."

f a group *d*, different from *a*, *b*, *c*, is introduced in place of one of naining *a* groups, then two different configurations are obtained,

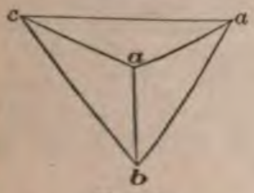


FIG. 2.

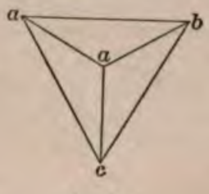


FIG. 3.

ling to whether the group *a* standing to the right or that to the left figure is replaced by *d*. These two configurations cannot be made rrespond to one another by turning.

one pictures one's self as standing at the point of attachment of the *a*, then in order to pass from *b* over *c* to *d* along the circumference e circle joining these three points it would be necessary to move in irection of the hands of a clock in one case (Fig. 4), and in the oppo- direction in the other (Fig. 5).

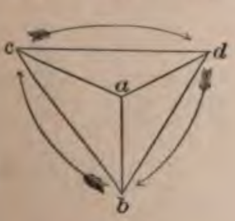


FIG. 4.

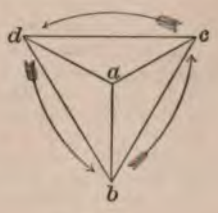


FIG. 5.

The two systems are not identical, but stand to each other in the same tion as an object stands to its image as reflected in a mirror, and many npounds which correspond to these systems crystallize in two different ms which bear a similar relation to one another. These are called antiomorphic crystals* (ἐναντιαῖος, opposite, enantiomorphism). Com- unds of this kind which contain an asymmetric carbon atom can be tically active, and this property, when the arrangement is that shown Fig. 4, is of an opposite quality from that when the arrangement as shown in Fig. 5.

As a matter of fact the isomeric compounds with one asymmetric car- on atom are identical in their chemical and mostly also in their physical properties with the exception of their optical behavior, since there are known two modifications of every compound with an asymmetric carbon atom (p. 39), one of which rotates the plane of polarization to the right and the other to the left (optical isomerism). When such compounds crystal- lize they also exhibit enantiomorphism.

ically. This modification cannot be split up into two opti- modifications, because on decomposition the molecule itself

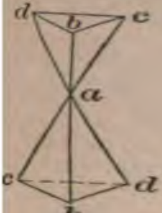


FIG. 10.

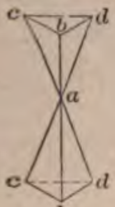
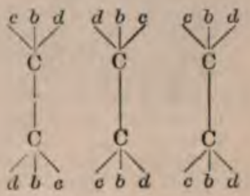


FIG. 11.

or



(Symbolic notation.)

FIG. 9. FIG. 10. FIG. 11.

Thus, for example, in Fig. 11, if the arrangement of the in the upper tetrahedron corresponds to a rotation to the he lower half of the molecule the arrangement corresponds o the right, while in Fig. 9 the arrangement *b*, *c*, *d* in both orresponds to a rotation to the left, and in Fig. 10 it cor- a rotation to the right, representing the two optically fications.

are present in the molecule of a compound two asymmetric to which are attached altogether six different groups (form- asymmetric molecule), for example, *cba*–C–C–*def*, then there ers possible, namely,

) $\frac{+A}{+B}$, (2) $\frac{+A}{-B}$, (3) $\frac{-A}{+B}$, (4) $\frac{-A}{-B}$,

d *B* represent the two tetrahedrons and + represents the of the atoms in a clockwise direction (i.e., dextrorotatory nd − represents the arrangement of the atoms in a counter- lævorotatory position.

ee asymmetric carbon atoms are present in a single asymmetric or example *hgf*C–*Cab*–C*cde* (as in the pentoses and their corre- cids), then there are eight isomers possible; if four asymmetric ns are present in an asymmetric molecule (as in the case of the there are sixteen isomers possible; so that in general for every l having *n* asymmetric carbon atoms there will exist 2^n isomeric ions (e.g., for four asymmetric carbon atoms $2^4 = 16$ isomers).

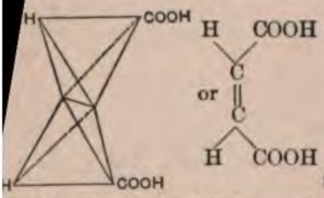
these isomers are optically active, because in the presence of atoms or atomic groups attached to the two asymmetric carbon compensation of the rotatory power can take place.

ddition to these active modifications it is still possible to have forms which are produced by the combination of two active mod- s for example, of 1 and 4, 2 and 3, but not of 1 and 2, or 2 and above).

n the case of compounds having three or more asymmetric carbon in a symmetric molecule, the number of possible isomers (as was for two asymmetric carbon atoms on p. 306, *a*) is small and these art optically active, but in part optically inactive, and cannot be into active modifications (because of intramolecular compensa- s in *a*, Fig. 11). In addition to these other inactive, resolvable es (racemic modifications, p. 39) are possible.

Isomerism in unsaturated compounds.

Compounds containing carbon atoms connected by double bonds. such cases the tetrahedrons corresponding to the asymmetric car- toms are connected together at two apices, namely, at one edge, therefore no rotation of the two tetrahedrons can take place about mmon axis. The atoms or atomic groups attached to each of the mmetric carbon atoms must therefore remain fixed in their original tions (see Figs. 12 and 13).



IG. 12.—Maleïc acid, $C_4H_4O_4$.

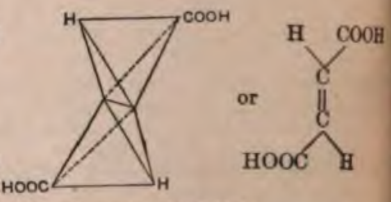


FIG. 13.—Fumaric acid, $C_4H_4O_4$.

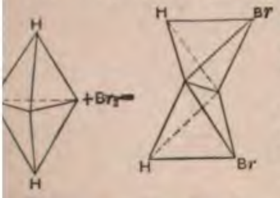
The conditions here are different on the right and left, although they esemble the conditions which exist when the asymmetric carbon atoms re attached by a single valence, and when two, three, or four different roups are attached to the tetrahedrons it is possible to recognize two somers of each which show a complete difference in almost all physical nd also in certain chemical properties.

Since the atoms or atomic groups which are attached to the asymmetric arbon atoms all lie in one plane, these compounds cannot be optically ctive.

According to the theory of structure both maleïc and fumaric acid nust have the same formula: HOOC−CH=CH−COOH. In a spatial repre- entation of these two substances a different structure is evident if for one cid we employ the so-called plane-symmetric or *cis* form (Fig. 12) for one cid and the so-called axial-symmetric or *trans* form (Fig. 13) for the other.

β. Compounds containing carbon atoms connected by triple bonds.

In this case the tetrahedrons corresponding to these carbon atoms are onnected by three apices, namely, by one of their faces, and therefore form a double triangular pyramid, so that the two free valences, just as in the above case *a*, lie in one plane. Isomers are here impossible.

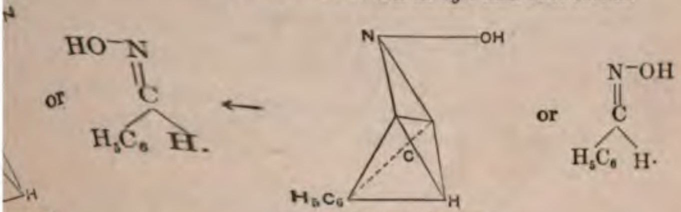


If one of the bonds is severed, then the two tetrahedrons swing apart. The two attached atoms or atomic groups will then lie one above the other and the molecule becomes plane-symmetric.

d. Isomerism in nitrogen compounds.

Isomers appear in the case of certain oximes, diazo- and azo-co ounds, in which a trivalent nitrogen atom is attached by two of

or nitrogen atom, which can be explained by the
ree nitrogen valences do not lie in a single plane but
e like the four free valences of the carbon atom in
three valences of nitrogen are imagined as directed
rs of a tetrahedron, the nitrogen atom itself being
th corner. In this way is represented, for example,
two isomeric benzaldoximes, HO—N=CH—C_6H_5, as
ers of this sort are known as *syn* and *anti* forms.



loxime.

Anti-benzaldoxime.

//

MINATION OF THE COMPOSITION, MOLECULAR AND CONSTITUTIONAL FORMULA.

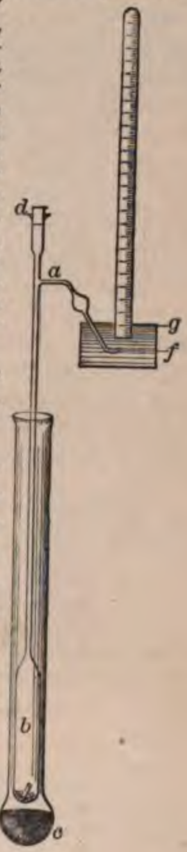
der to ascribe an empirical and rational molecular formula
o an organic compound the following essentials are necessary:
he elements, of which the compounds are composed, must
rmined (qualitative analysis).
The proportion in which the respective elements exist in the
und must be estimated (quantitative analysis).
The molecular weight must be determined with reference to
alitative and quantitative composition.
The intermolecular arrangement of the atoms or atomic groups
molecule (the constitutional formula) must be studied.

1. Qualitative Elementary Analysis.

he elements in an organic compound can generally only be
ted after the destruction of the molecule of the compound,
h may be done as follows:

he *carbon* in most organic bodies can be detected by their yield-
lack carbon on heating them in the absence of air. The carbon
be more positively detected by heating the substance with copper
e (p. 236) or if the substance is volatile, by passing the vapors
ly over heated copper oxide contained in a glass tube. The carbon
his case suffers oxidation at the expense of the oxygen of the

apor Density *by the Expulsion of Air according*
sel *b*, which is constructed of glass or porcelain
heated in the large tube *c* by
l contained therein (water,
e, boiling-point 183°; diphe-
310°), or by molten lead (at
temperature is constant or
s rise from the tube *a* at *f*. The
s full of water, is now adjusted
e *a* and the glass tube *b* opened
ount of the substance quickly
k at *d* quickly replaced. The
rizes and expels from *b* a quan-
ng to its vapor volume, which
d tube *g*. The volume of air read
oonds to an equal volume of the
e in question just as if it were
vapor of the substance at ordinary



ending upon the determination of
e boiling-point and depression of
p. 19).

n of the freezing-point or the
boiling-point for the molecular
in dilute solution is constant for
ces when equal quantities of the
e used. In order to find the con-
e freezing-point depression or the
levation (T) produced by a few
a substance of known molecular
issolved in 100 grams of the solvent
and then calculated upon the molec-
the respective substance as follows:

$= M : K$; hence $T \times M = P \times K$;

$$K = \frac{T \times M}{P}.$$

ms (P) of the substance of unknown molecular weight
in 100 grams of the solvent whose constant (K) has
ed and the depression of the freezing-point or elevation
point (T) determined and the molecular weight (M)
ding to the equation $M = \frac{K \times P}{T}$.

21 grams acetic acid (*P*) dissolved in 100 parts benzol
the freezing-point 2.222° (*T*), hence the molecular
d $M=\frac{49\times2.721}{2.222}=60$, which corresponds to the figure
por density and shows that the simplest formula ob-
by chemical analysis, $CH_2O=30$, must be double; that

thods.

iethods, on account of the ease with which they
ve replaced the chemical methods. The latter
different, depending upon the chemical properties
nvestigated.

id is an acid the molecular weight may be deter-
basicity has been learned by the analysis of its
lly the easily purified silver salt is used, which
ves metallic silver, which can be directly weighed
weight of the acid calculated from this result.
acid the quantity by weight which unites with 1
sents its molecular weight minus 1 atom hydrogen.

etic acid, which by analysis (p. 313) may have the
nultiple thereof, is a monobasic acid, and hence in its
is replaceable by 1 atom of a univalent metal. If
determine how much acetic acid is combined with
hen we obtain the molecular weight of acetic acid

rts silver acetate yield 64.68 parts silver on incinera-
rts are lost. The acetic acid united with 1 atom of
silver acetate will be 59 parts by weight:

$$64.68 : 35.32 :: 108 : x; \quad x=59.$$

Silver. At. wt. Silver.

acid, 1 atom H is replaced by 1 atom Ag, hence its
59 + 1 = 60, which corresponds to the formula $C_2H_4O_2$
be CH_2O, otherwise the molecular weight would be
$C_3H_6O_3$, because then the silver salt must contain $1\frac{1}{2}$
is impossible. The formulæ $C_4H_8O_4$, $C_6H_{12}O_6$ are
cetic acid was bi-, tri-, etc., basic.

base the molecular weight may be deter-
instance, all organic bases

base which unites with 2 molecules
weight of the base.

make use of the hydrochlorplatinic ac
the HCl salt, as this forms compounds cor
compound $(NH_4)_2PtCl_6$, having an analo
be prepared readily in a pure form gener
and leave platinum, which can be di
and the molecular weight calculated from i

compound is indifferent, then the molecular
by the preparation of simple substit
relationship of the individual co
weight, of which the compour
investigated after cleavage.

compounds containing hydrogen we can ger
halogen atom and the substitution produ
Naphthalin, according to analysis, has th
The analysis of bromnaphthalin sh
in $C_{10}H_8$ by one bromine atom, while the f
as we know of no compound in wh
replaced by halogens.
molecular weight cannot be determined
methods, the simplest formula found by
at the same time the law of even numb

Determination of the Constituti

a compound we have determined
weight (empirical molecular for
the compound by the forn
a confusion with other compoun
number of isomeric compounds a
the same composition and the san
on page 302 that four compound
and it is therefore necessary
circumstances which of these fou
simultaneously express the
construction, of the compou
The construction of a compound
formula (rational molecula

ch unites with 2 molecules HCl represents
the base.

e of the hydrochlorplatinic acid salt of the base
as this forms compounds corresponding to the
$NH_4)_2PtCl_6$, having an analogous composition.
adily in a pure form generally with water of
platinum, which can be directly weighed on
ular weight calculated from its weight.

different, then the molecular weight may often
eparation of simple substitution products, or
ship of the individual constituents having
, of which the compound is constructed,
cleavage.

ning hydrogen we can generally replace one H
nd the substitution product obtained can be
ording to analysis, has the formula C_5H_4 or a
sis of bromnaphthalin shows that one atom H
romine atom, while the formulæ $C_{20}H_{16}$, $C_{30}H_{24}$,
w of no compound in which $\frac{1}{16}$, $\frac{1}{24}$, etc., of the
ogens.

cannot be determined either by physical or
lest formula found by analysis must be suffi-
the law of even numbers must be considered

of the Constitutional Formulæ.

have determined the composition as well
ical molecular formula), still it is impossible
und by the formula thus obtained and to
other compounds. We have seen that a
compounds are possible, i.e., compounds
ion and the same molecular weight; thus we
our compounds having the formula $C_4H_{10}O$
fore necessary, as soon as it does not follow
of these four is meant, that the chemical
xpress the constitution or structure, i.e.,
the compound in question.

a compound as represented by the consti-
al molecular formula) is not the result of
out these formulæ must be derived from
sitions, cleavages, and methods of formation

rs are converted into alcohols by nascent
sulphonic acids give mercaptans:

H + 6H = C_2H_5–OH + $2H_2O + H_2S$;
Ethyl alcohol.
+ 6H = C_2H_5SH + $3H_2O$.
id. Ethyl mercaptan.

bon dioxide often gives important information
compound. Acetic acid heated with lime yields
= $CaCO_3 + CH_4$. Benzoic acid heated with lime
O = $CaCO_3 + C_6H_6$. From this it follows that
benzol in the same manner as acetic acid to
bodies which are obtained by splitting off of
fix *pyro*.
tion of compounds richer in carbon from those
ortance in the study of the constitution.
action of chlorine, we obtain methyl chloride,
erivatives of methane can be prepared. Carbon
he formation of acetylene, C_2H_2, which can be
H_4, and ethane, C_2H_6, by nascent hydrogen, and
of other compounds can be obtained. If acety-
be heated red-hot, it is converted into benzol,
umber of cyclic compounds may be obtained.
organic substances are decomposed by organic
t the sodium haloid salt is formed and the two
s CH_3–Na + CH_3Cl = CH_3–CH_3 (ethane) + NaCl.
sed into a sodium compound of a hydrocarbon,
her by one atom C is obtained: CH_3–Na + CO_2
ate).
s of the hydrocarbons of the methane series or
enzol series yield cyanides of the hydrocarbons
n cyanide (KCN). In these compounds the
nverted into the carboxyl group (COOH) on

= KCl + CH_3–CN (methyl cyanide);
= NH_3 + CH_3–COOH (acetic acid).

n the union of two or more molecules of the
substances forming one molecule by union
ally by the elimination of H_2O, HCl, NH_3, CO_2,
e split off from the new molecule by simple

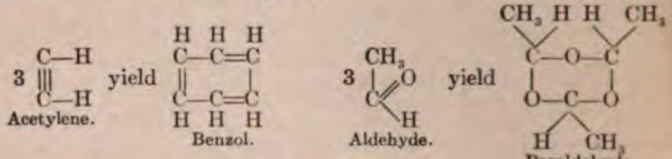
ce readily amongst the aldehydes and ketones
about by the direct action of two substances
ndensation is generally brought about by the
such as aluminium chloride, potassium bisul-
acetate, sodium hydroxide, hydrochloric acid,
e, etc.

Aluminium chloride brings about the union of chlorine derivatives the methane series with hydrocarbons of the benzol series: $C_6H_6+C_2H$ $=C_6H_5-C_2H_5+HCl$. $C_6H_6+2C_2H_5Cl=C_6H_4=(C_2H_5)_2+2HCl$. C_6H $3C_2H_5Cl=C_6H_3\equiv(C_2H_5)_3+3HCl$.

Concentrated sulphuric acid causes the union of combinations of t benzol series with aldehydes:

$$2C_6H_6+CH_3-CHO=CH_3-CH=(C_6H_5)_2+H_2O.$$

Polymerization depends upon the union of several similar molecul of a simpler constituted organic substance, without the elimination atomic groups, forming a complicated molecule. The original substanc can be readily split from this new molecule. Polymerization take pl with unsaturated hydrocarbons, aldehydes, and cyanogen compounds If compound contains a C atom united with a polyvalent element or radic by more than one valency, then at this position a rupture may take forming a simple union, whereby the molecules having these free affin unite with one another (see under example 2). In this case a union o molecules does not entirely take place through the C atoms as we fin condensation (see under example 1).



Acetylene. Benzol. Aldehyde. Paraldehyde.

2. *Physical Methods.*

Specific Gravity. This is different for isomeric compounds. The quo- tient of the specific gravity divided into the molecular weight, called the molecular volume (p. 36) of liquid organic compounds may give us infor- mation as to the constitution of the body if they are compared at certain temperatures such as, for instance, at their boiling-points. Thus many homologous series show an increase of the molecular volume of approxi- mately 22 for every additional CH_2 (ethyl alcohol molecular volume=62.5, butyl alcohol molecular volume = 84.8, etc.) when they have the same atomic grouping, and in many cases a deviation from this rule shows another atomic grouping.

Chlorine or bromine atoms substituted for H atoms in organic com- pounds occupy a greater volume when they are united to the same C atom as compared with different C atoms, etc.

Melting- and Boiling-points. Isomeric bodies have different melting and boiling-points. In general an organic body is more readily fusibl and more volatile the simpler the molecule is constituted, and the mor complicated the molecule is, the higher are the melting- and boiling points, and the molecules suffer decomposition readily by heat.

The boiling-point determination is an important aid in the inves tigation of the constitution of organic bodies. Homologous compound (i.e., those which differ from each other by CH_2) with the same atomi grouping show approximately the same variation in boiling-point, whil ric compounds with different atomic grouping differ markedly in g-point, thus:

		Boiling-point.	
Ethyl alcohol,	C_2H_6O	78.4°	Difference 19
Normal propyl alcohol,	C_3H_8O	97.4°	" 19.6
Normal butyl alcohol,	$C_4H_{10}O$	115.0°	
Acetic acid,	$C_2H_4O_2$	119.0°	" 22
Propionic acid,	$C_3H_6O_2$	141.0°	" 21
Normal butyric alcohol,	$C_4H_8O_2$	162.0°	

Amongst the isomeric aliphatic compounds the normal compounds ys have the highest boiling-point. The boiling-point becomes lower more branches the carbon chain has.

Of the disubstitution derivatives of benzol the ortho compounds nearly ays have a lower boiling-point than the meta and para compounds.

The melting-points also show certain relationships to the constitu- ion of the compounds.

Among the disubstitution products of benzol the para compounds arly always have a higher melting-point than the ortho or meta com- unds. With the normal acids of the formic and oxalic acid series the roduction of one CH_2 group causes a rise in the melting-point, while e next CH_2 group causes a lowering, so that the members of the series th uneven C atoms have a lower melting-point than both neighboring embers with even C atoms; thus,

ormic acid, CH_2O_2, melts at +8.4°; Acetic acid, $C_2H_4O_2$, at +17°
ropionic acid, $C_3H_6O_2$, melts at −22°; Butyric acid, $C_4H_8O_2$, at − 8°

With isomeric bodies the melting-point is higher the more side chains present.

Refraction of Light. The molecular refraction of liquid organic npounds is equal to the sum of the atomic refraction (p. 38).

The univalent elements in organic compounds have a constant atomic raction, while with the polyvalent elements the refraction is raised ording to the double or treble bonds (also for the C atoms).

In the homologous series the molecular refraction increases at a con- nt rate, namely, 4.5 for each CH_2 group.

Rotation of the Plane of Polarization. This also gives us information to the constitution of an organic compound, as an optically active anic compound must contain one or more asymmetric carbon atoms 39).

TRANSFORMATIONS AND DECOMPOSITIONS.

1. Action of Chemical Agents.

Oxygen at ordinary temperatures acts upon only a few combinations, ile at a red heat they all suffer combustion.

Active or nascent oxygen (from manganese dioxide, or potassium hromate and sulphuric acid) unites either directly, or removes H in form of water, or brings about both changes simultaneously.

give hydroxyl derivatives with watery solutions
$Cl + KOH = C_2H_5OH + KCl$.
li splits off all halogen atoms as halogen hydrogen
$+ KOH = CH_2 = CH_2 + KCl + H_2O$.
when fused with organic bodies oxidizes them, in
or H_2, and this last set free: $C_2H_5OH + KOH =$
complicated molecules are thereby split into

$O_6 + 6NaOH = 3C_2Na_2O_4 + 18H$.
ose. Sodium oxalate.

ide and phosphorus tribromide replace the hy-
rine or bromine respectively: $3C_2H_5OH + PCl_3 =$

lphide replaces the oxygen of the hydroxyl by

$_2H_5OH + P_2S_5 = 5C_2H_5SH + P_2O_5$.

ectly, or, as is generally the case, on heating under
tting (saponification or hydrolysis, which see).

2. Action of Heat.

ganic substances are heated in the absence of
heir elements regroup themselves so that besides
rbon dioxide, water, etc., a large number of or-
simpler composition are produced and carbon
e large number of volatile compounds thus pro-
condensed by cooling apparatus, the other part
aseous state. That portion which is condensed
rs, a watery layer which contains various bodies
her generally dark layer, which is called the tar.
hich are volatile without decomposing at certain
ecomposed with the deposition of carbon when
the gaseous state through red-hot tubes.

ation of brown and anthracite coal, etc., bituminous
the fabrication of illuminating-gas), street gas, ammo-
, tar and coke are obtained as decomposition products.
ains volatile hydrocarbons of the methane, ethylene,
natic series as well as some carbon dioxide, carbon
, air, and vapor of water, and when imperfectly puri-
ed hydrogen and sulphur dioxide (see Potassium Ferro-

cture of many constituents which may be separated by
on and may be divided into the following four groups,
hemical behavior:
rbons. These form the chief constituent, are indiffer-

th the law of even numbers (p. 314) the radicals with not exist free. If they are released from their comally double up or they decompose:

$_3I + CH_3I + 2Na = H_3C{-}CH_3 + 2NaI.$
methyl iodide. 1 mol. dimethyl.

with even valences can exist in the free state, when they n compounds in which the affinities set free belong to two bon atoms, so that they can unite together:

$ClH_2C{-}CH_2Cl + 2Na = H_2C{=}CH_2 + 2NaCl.$
Ethylene chloride. Ethylene.

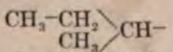
ollows that the radical $CH_3{-}CH{=}$ cannot be obtained from d $CH_3{-}CHCl_2$ because both free valences cannot be united ecule itself.

adicals are also called mono-, di-, etc., valent alcohol radi- their most important compounds, the alcohols. The t radicals are also called *alkyl*, the divalent *alkylene*, and ent *alkenyl* radicals.

ecial nomenclature for organic bodies can be based upon als. Thus methane, CH_4, can be considered as a combination ethyl radical with hydrogen and hence called methyl hydride, methyl alcohol, $CH_3{-}OH$, as methyl hydroxide; dichlor- e, $CH_2{=}Cl_2$, as methylene chloride; trichlormethane, $CH{\equiv}Cl_3$, henyl chloride, etc.

ong the monovalent radical we differentiate between the primary, ary, and tertiary, according to whether the unsaturated C atom is to one, two, or three other C atoms; thus,

$CH_3{-}CH_2{-}CH_2{-}CH_2{-}$
Primary butyl.


$\begin{matrix}CH_3{-}CH_2\\CH_3\end{matrix}\!\!>CH{-}$
Secondary butyl.

$(CH_3)_3{\equiv}C{-}$
Tertiary butyl.

n satisfying the free valence of these radicles with $-OH$, $-I$, etc., we in the primary, secondary, and tertiary compounds (pp. 333, 334). The radical $-COOH$ is called *carboxyl*, $-O(CH_3)$ *methoxyl*, $-O(C_2H_5)$ xyl, $-S(CH_3)$ *sulfmethyl*, $-COH$ *carbinol*, etc.

Letters or figures are added to the names of certain isomeric comnds in order to designate the position of certain atoms or radicals the molecule. Thus we designate the terminal C atom of acids well as the side-chain of cyclic compounds by ω or 1, the one comed therewith by α or 2, etc., and the terminal C atom of the remain- compounds by α or 1, etc.

Correspondingly we differentiate between

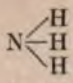
$CH_3{-}CHI{-}COOH$ α-iodopropionic acid. $CH_2I{-}CH_2{-}COOH$ β-iodopropionic acid.

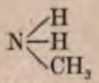
$CH_3{-}CH(OH)CH(CH_3){-}COOH$ α-methyl-β-oxybutyric acid. $CH_2(OH){-}CH_2{-}CH_2{-}$ γ-oxybutyric acid.

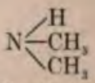
$CH_3{-}CH_2{-}CCl_3$ α-trichlorpropane. $CH_3{-}CCl_2{-}CH_2Cl$ α β β-trichlorpropane. $CH_2Cl{-}CHCl{-}CH_2Cl.$ α β γ-trichlorpropane

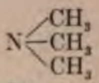
Optically active bodies (p. 39) are designated by *d*- (c when they turn the ray to the right, by *l*- (lævo) when the it to the left, and by *i*- when they represent the inactive mo tion.

Amines, amin bases, monamines, are to be considered as an whose H atoms are entirely or in part replaced by alkyl radica p. 329). According as one, two, or three alkyls are introduc obtain primary amines or amid bases, secondary amines o bases, tertiary amines or nitril bases (but not nitriles):


Ammonia.


Methylamine


Dimethylamine.


Trimethylamine

Diamines are derived from 2 molecules NH_3, in which each NH cule has one H atom replaced by one valence of one or more d alcohol radicals (alkylenes); thus,

$H_2N{-}C_2H_4{-}NH_2$ Ethylendiamine. $NH{=}(C_2H_4)_2{=}NH$ Diethylendiamine. $N{\equiv}(C_2H_4)_3$ Triethylendian

The triamines, tetramines, etc., have an analogous derivation whe valence of one or more multivalent alcohol radicals are introduce three, four, etc., molecules of NH_3; thus, $CH_3{-}C{\equiv}(NH_2)_3$, ethenyltri $(CH_2)_6N_4$, hexamethylene tetramine.

Nitrosamines are amines in which an H atom is replaced by the group $-NO$; thus, $(CH_3)_2{=}N{-}(NO)$, dimethyl nitrosamine.

Nitramines are amines in which one H atom is replaced by th group $-NO_2$; thus, $CH_3{-}NH{-}NO_2$, methylnitramine.

Imines, imin bases, are obtained when two H atoms in one mole ammonia are replaced by one alkylene radical: $C_3H_6{=}NH$, propyler

Nitriles (not nitril bases, see above) may be considered as am in which all three H atoms are replaced by an alkenyl radical $(CH_3{-}C){\equiv}N$, or also as a combination of alkyl with the radical gen $-C{\equiv}N$, e.g., $CH_3{-}C{\equiv}N$, methyl cyanide.

are formed by the replacement of the replaceable hydrogen anic or organic acids (p. 335) by alcohol radicals according a part of the replaceable hydrogen of the acid is replaced, n the formation of salts. Thus monobasic acids yield only hile multibasic acids yield both esters and ester acids:

$KOH + HCl = KCl + H_2O.$

$C_2H_5OH + HCl = C_2H_5Cl + H_2O.$

Ethyl alcohol. Ethyl chloride.

$KOH + H_2SO_4 = KHSO_4 + H_2O.$

$C_2H_5OH + H_2SO_4 = C_2H_5{-}HSO_4 + H_2O.$

Ethyl alcohol. Ethyl sulphuric acid.

$K_2O + H_2SO_4 = K_2SO_4 + H_2O$

$(C_2H_5)_2O + H_2SO_4 = (C_2H_5)_2SO_4 + H_2O.$

Ethyl ether. Ethyl sulphate.

neric Alcohols, Aldehydes, Ketones. The isomeric alcohols ided into *primary*, *secondary*, and *tertiary* according to their l behavior, due to the position of the HO groups.

have seen (p. 302) that in the substitution of one H atom by alent element or radical in propane, C_3H_8, two isomers are , namely, $CH_3{-}CH_2{-}CH_2(OH)$ and $CH_3{-}CH(OH)CH_3$; also that he two butanes, C_4H_{10}, four isomeric substitution products are ; in other words, that by the substitution of one OH group e of one H atom the existence of two or of four alcohols, respectre made possible. These four alcohols are known, and the strucven on page 302 corresponds in fact to their chemical behavior.

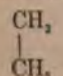
imary alcohols by oxidation are converted into aldehydes alcohol dehydrogenatus) by the removal of two intraradical hyn atoms (belonging to the alcohol radicals). On further action ldehydes take up one O atom very readily and are converted acids (p. 335). Each primary alcohol has a corresponding aldeand an acid with the same number of C atoms; thus,

✓P
329✓

lethyl alcohol, $CH_4O + O = H_2O + CH_2O$, Methyl aldehyde.

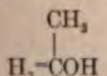
lethyl aldehyde, $CH_2O + O = CH_2O_2$, Formic acid.

his behavior can be explained if we admit that in the primary ols one hydroxyl replaces one hydrogen atom of a CH_3 group ence we have still two oxidizable H atoms in the group; thus,



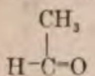
$$\begin{array}{c}CH_3\\ |\\ CH_3\end{array}$$

Ethane.



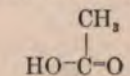
$$\begin{array}{rcl} & CH_3 & \\ & | & \\ H_2{=} & C & OH\end{array}$$

Ethyl alcohol.



$$\begin{array}{rcl} & CH_3 & \\ & | & \\ H{-} & C & {=}O\end{array}$$

Ethyl aldehyde.



$$\begin{array}{rcl} & CH_3 & \\ & | & \\ HO{-} & C & {=}O\end{array}$$

Acetic acid.

Primary alcohols contain the group $^{-}CH_2(OH)$.

Aldehydes contain the group $^{-}CH{=}O$.

Secondary alcohols are isomeric with the primary alcohols, s oxidation they at first also lose two hydrogen atoms and form k which are isomeric with the aldehydes. On further oxidati ketones yield acids which contain a less number of carbon a thus,

$$\underset{\text{Secondary propyl alcohol.}}{CH_3{-}CH(OH){-}CH_3} + O = \underset{\text{Propyl ketone.}}{CH_3{-}CO{-}CH_3} + H_2O.$$

$$\underset{\text{Propyl ketone.}}{CH_3{-}CO{-}CH_3} + 4O = \underset{\text{Acetic acid.}}{CH_3{-}COOH} + CO_2 + H_2O.$$

This behavior is to be explained by the fact that in the secondar hols the hydroxyl replaces one H atom of the $=CH_2$ group, and the $=CH(OH)$ thus produced cannot be converted into the CO(OH) without the splitting off of a neighboring C atom. As the $-CH(OH$ can exist only in such saturated compounds as contain at least C atoms, then the lowest secondary alcohol must contain three C a

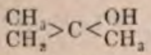
Secondary alcohols contain the group $=CH(OH)$.

Ketones contain the group $^{-}CO^{-}$, which is united to carbon on both sides.

Tertiary alcohols are compounds, isomeric with the prima secondary alcohols, which on oxidation are immediately transf without the formation of intermediate products, into various or ketones and acids, containing less amount of carbon:

$$\underset{\text{Tertiary amyl alcohol.}}{(CH_3)_2(C_2H_5)\ C{-}OH} + 3O = \underset{\text{Acetic acid.}}{CH_3{-}COOH} + \underset{\text{Propyl ketone.}}{CH_3{-}CO{-}CH_3} + H$$

They contain the hydroxyl in the place of the H atom of the group, and as the $CH\equiv$ group can exist only in saturated comp which contain at least four C atoms, the lowest tertiary alcoho contain four C atoms:



$$\begin{matrix}CH_3\\CH_2\end{matrix}>C<\begin{matrix}OH\\CH_3\end{matrix} \text{ or } (CH_3)_3{\equiv}C{-}OH\text{, tertiary butyl alcohol.}$$

These alcohols contain no more oxidizable hydrogen attac the hydroxylated carbon, hence they change immediately in th stages of oxidation

The tertiary alcohols contain the group $\equiv C{-}OH$, which i bined to the C atoms by its three valences.

Sometimes the isomeric alcohols are considered as derivat methyl alcohol or carbinol, $CH_3{\cdot}OH$, whose H atoms are repla alkyls and are called:

$C_3H_7{-}CH_2{\cdot}OH$, propyl carbinol, primary butyl alcohol;
$(CH_3)_3{\equiv}C{\cdot}OH$, trimethyl carbinol, tertiary butyl alcohol;
$(C_2H_5)(CH_3){=}CH{\cdot}OH$, methyl ethyl carbinol, secondary butyl a

Acids are formed on the oxidation of primary alcohols, when the two hydrogen atoms which are united with the hydroxyl group to the same C atom are replaced by an O atom, or when an oxygen atom is added to the aldehydes (p. 333). The carboxyl group $-COOH$ is characteristic of the acids. All acids contain two hydrogen atoms less and one oxygen atom more than the alcohols from which they are derived. While in inorganic acids nearly all the H atoms present are replaceable with the formation of salts, with the organic acids only so many replaceable H atoms are available in the formation of salts or esters (p. 332), as there are $-COOH$ groups present.

The basicity of organic acids is dependent upon the number of carboxyl groups contained, while the atomicity is dependent upon the number of hydroxyl groups present:

CH_3-COOH, Acetic acid. Monatomic and monobasic.	$CH_2(OH)COOH$, Glycolic acid. Diatomic, but monobasic.	$HOOC-COOH$, Oxalic acid. Diatomic and bibasic.
CH_3-COOK, Potassium acetate.	$CH_2(OH)-COOK$, Potassium glycolate.	$KOOC\ COOK$, Potassium oxalate.
$\begin{matrix}CH_3-COO\\CH_3-COO\end{matrix}>\overset{II}{Ca}$, Calcium acetate.	$\begin{matrix}CH_2(OH)COO\\CH_2(OH)COO\end{matrix}>\overset{II}{Ca}$, Calcium glycolate.	$\begin{matrix}COO\\COO\end{matrix}>\overset{II}{Ca}$, Calcium oxalate.

The hydrogen present in organic acids but not available for the formation of salts or esters (intraradical) may also be replaced by atoms or groups of atoms whereby the ability of the acid to form salts, etc., is in no wise changed; thus,

$CH_2(NO_2)-COOH$, Nitroacetic acid.	$CH_2(NH_2)-COOH$, Amidoacetic acid.	$CH_2(OH)-COOH$, Oxyacetic acid.
$CH_2(NO_2)-COONa$, Sodium nitroacetate.	$CH_2(NH_2)-COOK$, Potassium amidoacetate.	$CH_2(OH)-COONH_4$, Ammonium oxyacetate.

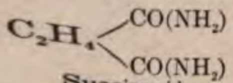
Imido-acids are derived from the acids by the replacement of the $O=$ atom of the $-COOH$ group by $=NH$. They are only known in the form of their esters, the imido ethers; thus, $CH_3-C(NH)O(CH_3)$.

Thio-acids. The oxygen of the COOH groups of acids can be replaced by sulphur and from these acids many compounds are derived:

CH_3-COSH, Thioacetic acid.	$CH_2(NH_2)-COSH$, Amidothioacetic acid.	CH_3-CSSH, Dithioacetic acid.
CH_3-COSK, Potassium thioacetate.	$CH_3COS(C_2H_5)$, Ethyl thioacetate.	$(CH_3-CO)_2S$, Thioacetic anhydride.

Imidothio-acids are derived from the thio acids by replacing the $=O$ atoms of the $-CO{\cdot}SH$ groups by $=NH$. They are only known in the form of esters, the imidothio-ethers.

mides. Among the polybasic acids there
also acid amides or amine acids according
arboxyl groups be present; thus,
$_2$)
I
d.



$$C_2H_4\genfrac{}{}{0pt}{}{\diagup CO(NH_2)}{\diagdown CO(NH_2)}$$

Succinamide.

e hydroxyls of the carboxyl groups are re-
oup, NH_2. In the amine acids the hydroxyls
are only in part replaced by NH_2.
ned when acid radicals replace the hydrogen in
us, $H_2N-NH(CH_3-CO)$ = acetyl hydrazid.

. The different atomic groups which we have
c for the various compounds may exist simul-
me molecule, producing bodies having mixed
hyde alcohols or aldoses with the groups CHO
H or COH), aldehyde acids with the groups CHO
e alcohols or ketoses with the groups CO and
ds with the groups CO and COOH, amido-alcohols
$_2$ and CH_2OH, etc., amido-ketones with the groups
do-aldehydes with the groups NH_2 and CHO.

2. International Nomenclature.

for the present only in the publication of chemical
d large chemical works. It is based upon substi-
mpound is considered as a derivative of a hydro-
is is obtained if we replace all the other atoms or
present in the respective C compound by the corre-
ber of hydrogen atoms. Accordingly $CH_2=NOH$ is
oxime, but methanoxime; $CH_3-CO-NH_2$ not acetamide,
le; CH_3-CH_2-CN not propionitrile, but propane-nitrile.

ydrocarbons with branchless chains terminate in *ane;* there-
nly one butane and one pentane, etc. Hydrocarbons with
ns are to be considered as derivatives of normal hydrocar-
r name is formed from the longest normal chain which the
ns to which the name of the side chain is added; thus,

$_3$ is not called isobutane, but methyl propane;

$-CH_2-CH_3$ is not called heptane or triethyl methane, but rather ethyl pentane.

then we
yl, ethyl,
following
yl heptane

carbon atom
rs beginning

$$\overset{2}{CH_2}-\overset{1}{CH_3}$$
CH_3
pentane 3.
carbons is also

$-CH_2-CH_2Br.$
bromopentane.
uble bond have
triene, etc.; for
xadiene instead of
arbons with triple bond
$-C\ C-C \equiv CH,$ If
ke use of the termination
ition of the multiple bond
at which it occurs:
butene 2.
3, 4, 5, 6 CH_2 groups,
called *cyclanes* and have
carbons with the prefix
e.
end in *-yl*; e.g., CH_3-CH_2-
yl.
tions end in *-ol*; e.g.,
e.g., $-CH_2-CHO$, ethylal
ination *-oyl* added to the original
=ethanoyl.
yllable *-ol* attached to the
polyatomic alcohols have di-, tri-,
OH, ethyl alcohol=ethanol,
glycerin = propantriol
bonds, in *-enol* or
the ethenol, $CH_2=CH-CH_2OH$,
H, propargylic alcohol=
comes from ethenol, and all
COH-group are called
ing *-ary* between the
hyl ether, $(C_2H_5)O=$

Sulphur ethers have *-thio*, *-dithio*, and *-sulfon* intr
$C_6H_5-S-C_2H_5$, benzenthioethane, $C_6H_5-S-S-C_6H_5$, benzen
$C_6H_5-SO_2-C_6H_5$=benzensulfonbenzene.
Aldehydes have the termination *-al* attached to the
sulphaldehydes *-thial*; for example, HCOH, methanal, CH
thial.

Ketones have the final syllable *-on*, the diketones, tri
ketones, the termination *-dion*, *trion*, *-thion*; e g., CH_3-
panon, $CH_3-CO-CH_2-CO-CH_3$, pentadion 2, 4.
Acids are designated by adding -acid, -diacid, -triacid t
hydrocarbon with the ending *ic*; e.g., CH_3-COOH, ethanic
of acetic acid, $C_2H_4(COOH)_2$, butanic diacid instead of su
with mixed acids to the name of the respective alcohol, ket
2-propanolic acid instead of ethylidene lactic acid, CH_3-CH
propanolic acid instead of ethylene lactic acid, CH_2-OH
etc. Thioacids with a S atom simply united to the C at
thiolic acids; with doubly united S atom, *thionic acids;* e.g.,
ethanthiolic acid, $CH_3-CS(OH)$, ethanthionic acid, CH_3C
thiolthionic acid.

Salts and **esters** end in *-ate;* thus, $(CHO_2)_2Ca$, calciu
instead of calcium formate, $(COO)_2K_2$, potassium ethan
of potassium oxalate.

CLASSIFICATION.

All aliphatic compounds are formed by replacing all
the H atoms of the limit hydrocarbons (see p. 34
atoms or groups of atoms. Consequently the aliphati
will be treated in the following pages, according to th
side groups they contain, as compounds of mono-,
valent alcohol radicals (p. 328), or in short as mono-,
valent compounds. In connection with these compou
discuss those compounds which have a close genetic
while the carbohydrates will be specially discussed in o
the subject easier.

COMPOUNDS OF MONOVALENT ALCOHOL RAD

1. Monovalent Alcohol Radicals.

General formula C_NH_{2N+1}.

They cannot exist in the free state (p. 328). If an
substituted in the saturated hydrocarbons C_NH_{2N+2}, the
carbon residue C_NH_{2N+1} behaves like a monovalent ra
are called alkyls, specially methyl, ethyl, propyl, etc. (p.

mediate members have an odor similar to perspiration and are less soluble in water. From $C_{10}H_{20}O_2$ upward the acids are solids, insoluble in water, generally without taste or odor and can only be distilled without decomposition in a vacuum.

All the members of this series are readily soluble in alcohol and ether and are, with the exception of formic acid, acted upon only with difficulty by oxidizing agents. Carbon dioxide expels them from their componnds.

Besides the replacement of the hydrogen of the COOH group by metals (salt formation), by alcohol radicals (ester formation) and acid radicals (anhydride formation), we can also replace the hydroxyl of the COOH group by atoms or groups of atoms, also the non-replaceable (intraradical) hydrogen.

In this last case bodies having all the properties of the acids are obtained, as the COOH is still intact (p. 335). These acids are designated α, β, γ, see p. 330.

Every fatty acid can be reduced to its aldehyde if a salt of the acid is heated with a formic acid salt (a formate):

$$\underset{\text{Sodium acetate.}}{CH_3-COONa}+\underset{\text{Sodium formate.}}{H-COONa}=\underset{\text{Ethyl-aldehyde.}}{CH_3-CHO}+\underset{\text{Sodium carbonate.}}{Na_2CO_3}.$$

On the distillation of a salt of the fatty acids with caustic alkalies the carboxyl group is split and replaced by hydrogen, yielding hydrocarbons which contain one C atom less than the acid used: e.g.,

$$\underset{\text{Sodium acetate.}}{CH_3-COONa}+NaOH=\underset{\text{Methane.}}{CH_3-H}+Na_2CO_3.$$

On the dry distillation of the calcium salts of the fatty acids ketones are obtained:

$$(CH_3COO)_2Ca=CH_3-CO-CH_3+CaCO_3.$$

If a galvanic current is passed through a concentrated solution of an alkali salt of the fatty acids, the alkali metal is set free at the negative pole, with a decomposition of the water and the liberation of hydrogen, while at the positive pole carbon dioxide and a saturated hydrocarbon are set free:

$$2CH_3-COONa=C_2H_6+2CO_2+2Na.$$

From this behavior, as well as from the means of formation, it is evident that the fatty acids contain alkyl as well as a carboxyl groups.

cohols in the same manner as

$=H_3PO_3+3HBr.$

$H)=H_3PO_3+3CH_3Br.$

d by the action of the halogens upon the limit hydro-
erivatives are to be prepared according to this last
lies must be added at the same time in order to
d (see p. 322).

prepared by the action of the halogens upon the hy-
e Olefines). By the further action of the halogens
erivatives all of the hydrogen can be replaced atom

ives (p. 329) are obtained by the action of halogen
dary alcohols, also upon the alkylenes from C_3H_6
logens are attached to the carbon atom poorest in
the terminal carbon atoms:

$–CH=CH_2+HI=CH_3–CHI–CH_3.$

ydric alcohols with HI we generally obtain their
atives.

s (p. 329) are prepared by the action of halogen
hols (see also Olefines).

$l_3(NO_2)$, chlorpicrin, is obtained from many hydro-
eous action of chlorine and nitric acid as a color-

Methyl Alcohol, Wood Spirits, Wood Alcohol,

ccurrence. Methyl alcohol exists with acetic
in the watery distillation products of wood
so as salicylic acid ester in the Galtheria pro-
en). It is formed to a slight extent in the
many fruits.

de wood vinegar is neutralized with lime
cetic acid and the product distilled. The
tained is treated with calcium chloride,
pound $CaCl_2+4CH_3(OH)$, and this can be
ecomposing, while the volatile impurities
treated with water, when the compound
ts, and distilled, when the methyl alcohol

boiling at 67° and having a peculiar
uble in water and yields formaldehyde
n.

yde, Methanal, CH_2O or $H–CH=O$.
pors and air are passed over incan-

es give aldoximes (p. 331):
$-CH_3-CH=N(OH)+H_2O$.
they give so-called *alcoholates:*
$O+C_2H_5OH=CH_3-CH\langle\begin{smallmatrix}OH\\OC_2H_5\end{smallmatrix}$;
he elimination of water the aldehydes form so-
$OH)=CH_3-CH(OC_2H_5)_2+H_2O$ (ethylal).
they form *mercaptals*, corresponding to the
$C_2H_5-SH)=CH_3-CH(SC_2H_5)_2+H_2O$.
yanides of the next highest oxyacid (see Lactic
drocyanic acid:
$+HCN=CH_3-CH(OH)(CN)$.
form aldehyde ammonias, $CH_3-CH(OH)(NH_2)$,
f that with formaldehyde, p. 350) yield pyridin
enylhydrazin, $C_6H_5-HN-NH_2$, the aldehydes
elimination of water, generally forming insol-
zons:
$N-NH_2=C_6H_5-HN-N=CH-CH_3+H_2O$.
rves in the detection of the aldehyde and
thesis of sugars (see Carbohydrates).
n the exception of formaldehyde they are
ation of the corresponding primary alcohols
onding acids or their salts with a formate:
$COONa=Na_2CO_3+CH_3CH=O$.
Acetaldehyde.
formate.
vatives of the hydrocarbons by boiling with
$I_3-CH=O+2HCl$.
SH, occurs to a slight extent in human
the urine after eating asparagus, and is
on and putrefaction of many foodstuffs.
at 60° and has a nauseating odor.
methylsulphur ether, is a liquid having
g at 116°.

ers in General (p. 332). 1. Both are col-
luble in water and having a nauseating
acid and readily form salts with bases
mercaptides, $(CH_3-S)_2Hg$. In the air
isulphides: $2CH_3-HS+O=(CH_3)_2S_2+$
hey yield sulphonic acids (which see):
$=CH_3-SO_3H$.

this

$CCl_3-CHO+($

with peculiar odor,

h gives all the reactions of the aldehydes.
loracetic acid, CCl_3COOH, by means of nitric a
ies it is decomposed into chloroform and a forma

$$CCl_3-CHO+KOH=CHCl_3+HCOOK$$

This process takes place in the preparation of chlorof
rine of the chloride of lime forms chloral with the a
ium hydroxide which is always present in the chloride
es this chloral into chloroform and calcium formate:

$$2CCl_3-CHO+Ca(OH)_2=2CHCl_3+\begin{matrix}HCOO\\HCOO\end{matrix}\Big>Ca.$$

When chloral is treated with a little water it solidifies t
ystals of chloral hydrate, $CCl_3-CH(OH)_2$, which melt at 58
adily soluble in water with a bitter taste. This is the form
hloral is used in medicine. Chloral hydrate is an excellent
or many bodies, such as resins, starch, etc.

Chloral formamide, $CCl_3-CH\Big<\begin{matrix}OH\\CO(NH_2)\end{matrix}$, is obtained by bringing chl CCl_3-CHO, and formamide, $H-CO-NH_2$, together. It forms colorl odorless, but bitter crystals which are soluble in 20 parts water and whi melt at 114°.

Acetic Acid, $C_2H_4O_2$ or CH_3-COOH. *Occurrence.* Acetates are found in the animal kingdom, and free acetic acid is found in the feces, urine, perspiration, and several parenchymatous gland extracts. Pathologically it is found in leucæmic blood and gastric juice. It occurs free or as calcium or potassium acetate in the juice of many plants. Triacetin, $C_3H_5(C_2H_3O_2)_3$, occurs in the oil of the Evonymus europæus and Croton Tiglium; octyl acetate, $(C_8H_{17})C_2H_3O_2$, in the seeds of Heracleum giganteum and Heracleum sphondylium. Besides other products it is found in the putrefaction, fermentation, and dry distillation of many organic bodies.

Preparation. 1. From alcohol. If 8 to 15 per cent. alcohol is allowed to slowly trickle over wood shavings previously moistened with vinegar and pressed into barrels with false bottoms, the al is finely divided and spread over a greater surface, wh cent. water has the same specific gravity as it is impossible to determine the amount of s by means of the specific gravity, and this means.

exception of the silver and mercurous s, readily soluble in water. On heating, d and leave a residue; the alkali ace- d the other acetates metallic oxides or

n acetate with sulphuric acid the charac- is developed; if alcohol is added to this roduced, which is detected by its odor. tes with As_2O_3 the disagreeable-smelling tained.

O_2, is obtained by dissolving potassium onate in acetic acid and evaporating to lline powder which absorbs moisture from

$+3H_2O$, forms colorless efflorescent crystals ter.

$NH_4)O_2$, decomposes on heating into water $H_4=CH_3-CO-NH_2+H_2O$.

$IO-Al=(C_2H_3O_2)_2$, is only known in solution. n having a specific gravity of 1.048 is used

$)_2+3H_2O$, is obtained by dissolving lead porating. It forms colorless prisms which r and which have a sweetish taste; hence it .

ad Subacetate, $Pb(C_2H_3O_2)_2+xPbO$. Solu- ily dissolve lead oxide with the formation y be precipitated by alcohol as white g the following structure:

$-Pb-O-Pb-O-Pb-OOC-CH_3$;

$)-Pb-O-Pb-OOC-CH_3$.

ad oxide in lead acetate solution is called solution quickly absorb carbon dioxide, cloudy in the air as well as on the addition the precipitation of basic lead carbonate

OCl, is prepared by the distillation of phos-
etic acid: $3CH_3COOH + PCl_3 = 3CH_3-COCl +$
irritating liquid boiling at 55°.

in General. 1. They are irritating, fuming
change their halogens for other elements or
r they yield the original acid:
$l + HOH = CH_3-COOH + HCl.$
orm esters:
$C_2H_5-OH = CH_3-COO-C_2H_5 + HCl.$
l amides are produced:
$l + NH_3 = CH_3-CO-NH_2 + HCl.$
salts of organic acids they form acid anhydrides:
$CH_3-COONa = (CH_3CO)_2O + NaCl.$
alcohols are formed with zinc alkyls.
e same manner as acetyl chloride.

anhydride, $(CH_3CO)_2O$, prepared from acetyl
tate (see above, 5), is a colorless liquid with
and boiling at 180°. It does not at first mix
lly it decomposes into acetic acid therewith:
$O-OC-CH_3 + H_2O = 2CH_3-COOH.$

in General. 1. They are liquids or solids having
luble in alcohol and ether.
are transformed gradually into the free acid, and
the esters of these acids:
$+ 2C_2H_5-OH = 2C_2H_5(C_2H_3O_2) + H_2O.$
y cannot be prepared by simply abstracting water
nce by P_2O_5, but are obtained from the alkali salts
n of acid chlorides (see Acid Chlorides, 5).

$O-NH_2$, forms colorless crystals which melt
and are readily soluble in water and alcohol.

ral. 1. They are generally crystallizable, volatile
mides are neutral in reaction, but as they contain
, they unite, like ammonia, directly with acids.
ounds: $(CH_3-CO-NH_2)HNO_3$. The amido group
to the acid radical, of having one of the H atoms
$H_3-CO-NH)_2Hg$, mercuric acetamide.
ary amides are indifferent bodies.
acids or alkalies they decompose into their com-
up of water:
$O-NH_2 + H_2O = CH_3COOH + NH_3.$

and in the mineral water of Weilheim and
ared by the oxidation of propyl alcohol or
6, 2). It is a strong irritating liquid, boiling
ble in water. It can be separated from its
id swimming on the surface by the addition
reto. This property and the fact that its
is the origin of its name (πρῶτον, the first;

, alanin, $CH_3-CH(NH_2)-COOH$, is a cleavage
d forms needles which melt at 250°.
, levulinic acid, $CH_3-CO-CH_2-CH_2-COOH$ (p.
ng most carbohydrates with dilute hydrochloric
s colorless plates which melt at 33°.
pyl alcohol, $CH_3-CH(OH)-CH_3$, is prepared
l methods (p. 344) and is a colorless liquid

etone, C_3H_6O or $CH_3-CO-CH_3$, is found in
nan urine, in the blood, transudations and
r quantities in the urine of diabetics. It is
lation of isopropyl alcohol and in the dry dis-
, citric acid, sugar, wood, and hence occurs
hol. Ordinarily it is obtained by the dry
calcium acetate (p. 372, 8).
id, smelling like peppermint, and boiling at
ter, etc., and on oxidation it decomposes into
oxide:
$_3+4O=CH_3-COOH+H_2O+CO_2$.
d caustic alkali it yields iodoform (p. 347).
y hydrochloric acid gas or by concentrated

$H_3)_2=C=CH-CO-CH_3$ (Mesityl oxide);
$H_3)_2=C=CH-CO-CH=C=(CH_3)_2$ (Phoron);
H_{12} (Mesitylene).

. 1. They are similar in physical properties to
behavior towards acid alkali sulphites, hydro-
razin, but they do not reduce ammoniacal silver

with alcohols, but on the contrary they com-
the elimination of water and the formation of
gous to the mercaptols (p. 351, 8):
$H_5-SH=(CH_3)_2=C=(SC_2H_5)_2+H_2O$.

ry, two cyanogen radicals are possible according as alent element, the so-called nitrile group, N≡C−, t element, the so-called isonitril group, C≡N−, ts or groups combined with the cyanogen radicals gen or to carbon. According to another conception as a tetravalent element in the nitriles and as a in the isonitriles: N C− or C=N−. its compounds with H, −OH, −SH, −NH_2, Cl, etc., to either one or the other formula; still only one of des exists free, as the other contains the atoms in rium, which in the preparation of the respective com- diately converted into the stable form of the other tomerism, p. 300). Nevertheless the two isomers of es of the above-mentioned compounds are known, uced by the introduction of alkyls in place of hydrogen

en, cyanogen, C_2N_2 or N≡C−C≡N. *Occurrence.* To a in the gases of the blast-furnace and in illuminating- *n.* By heating ammonium oxalate: $(NH_4)OOC-COO(NH_4)$ $_2O$. It is, according to this, the nitrile of oxalic acid, OH, and has the structure N≡C−C≡N. With water it y converted into ammonium oxalate, taking up H_2O. *ation.* By heating silver or mercuric cyanide (p. 386): $=C_2N_2+Hg$; also by heating a solution of copper sulphate assium cyanide: $4KCN+2CuSO_4=C_2N_2+2CuCN+2K_2SO_4$. t be obtained by the direct union of carbon and nitrogen assium Cyanide).

perties. Colorless, irritating, poisonous gas which liquefies 2°; it is inflammable, burning with a purple-red flame into n dioxide and nitrogen. Water dissolves 4 volumes, and alcohol volumes. Potassium burns in C_2N_2 to potassium cyanide, KCN, d potassium hydrate absorbs the gas with the formation of potas- ium cyanide and potassium cyanate:

$$2KOH+C_2N_2=KCN+NCOK+H_2O \text{ (analogous to chlorine).}$$

Hydrocyanic Acid, Prussic Acid, HCN. *Occurrence and Formation.* Free in Pangium edule, certain Araceæ and Hydrocarpus varieties

o groups, the salts of one group being po
it in the cold by inorganic acids with th
etallic cyanides and formation of hydrocyanic
Cl=KCl+HCN+AgCN, while the salts of the
n-poisonous and split off in the cold with dilute
plex acids, so that the compound must be con-
these acids. To this group belong the compounds
rric, manganous and manganic, cobaltic, chromic,
es, with the alkali cyanides; thus $Fe(CN)_2+4KCN=$
the anion FeC_6N_6, which decomposes with acids as

$FeC_6N_6 + 4HCl = H_4FeC_6N_6 + 4KCl$.
errocyanide. Hydroferrocyanic acid.

$PtC_4N_4 + 2HCl = H_2PtC_4N_4 + 2KCl$.
platinocyanide. Hydroplatinocyanic acid.

$CoC_6N_6 + 3HCl = H_3CoC_6N_6 + 3KCl$.
cobalticyanide. Hydrocobalticyanic acid.

ids the hydrogen is not only replaceable by alkali
o by other metals. The salts of hydroplatinocyanic
tiful colors. Barium platinocyanide, $BaPtC_4N_4$, is used
of Röntgen rays.

cyanic Acid, $H_4Fe''C_6N_6$. (In six condensed hydro-
olecules we have two hydrogen atoms replaced by a
tom.) If an inorganic acid is added to a cold concen-
solution of potassium ferrocyanide, $H_4Fe''C_6N_6$ sepa-
white crystalline powder.

ts of this acid, the ferrocyanides, the potassium salt, the
cupric salts are of importance, as it is in this form that
cupric compounds are detected.

m Ferrocyanide, Yellow Prussiate, $K_4FeC_6N_6$. *Prepara-*
errous salt solution is treated with potassium cyanide,
is obtained of ferrocyanide, $Fe(CN)_2$, which dissolves in
potassium cyanide, producing potassium ferrocyanide:

$$Fe(CN)_2+4KCN=K_4FeC_6N_6.$$

d iron or ferrous sulphide also dissolves when treated with
ution of potassium cyanide. Oxygen is taken up from the

$$Fe+6KCN+H_2O+O=K_4FeC_6N$$

rcu acetonitrile, NC−CHg(NO_2), ess viol the percussion cap. th compo obtained as colorless crystals if a solution ctive metal in nitric acid is gradually treated with an excess of a decompose into hydroxylamin and formic acid with HCl:

$$C_2HgN_2O_2+2HCl+4H_2O=HgCl_2+2CH_2O_2+2NH_2(OH).$$

b. Carbylamine or Isonitrile.

Properties. In the isonitriles the nitrogen exists as a pentavalent ent (p. 383), so that the alkyls are united to the still free fifth vale nitrogen: $C\equiv N-CH_3$. Isonitriles are very poisonous, disagreeable-sm ng, colorless liquids, either insoluble or difficultly soluble in water. On heating with water to 180°, also by dilute acids even in the cold, b not by bases, they are split into formic acid and amines, at the same tim taking up water. From this it follows that the alcohol radical is unite to the nitrogen of the cyanogen:

$$CH_3-N\equiv C+2H_2O=CH_3-NH_2+CH_2O_2.$$

Preparation. 1. By warming chloroform and primary amine bases with alcoholic potash solution: $CH_3-NH_2+CHCl_3=CH_3-N\equiv C+3HCl$. (Hofmann's carbylamine test for primary amines; secondary and tertiary amines do not give isonitrile, and hence not the characteristic disagreeable odor.)

2. By the action of alkyl iodides upon silver cyanide:

$$CH_3I+AgNC=CH_3-N\equiv C+AgI.$$

(According to this reaction silver cyanide contains the N≡C group.)

3. Compounds of Cyanogen with Halogens, etc.

The hydrogen of hydrocyanic acid is not only replaced by metals and alcohol radicals, but also by halogens and monovalent atomic groups: −OH, −SH, $-NH_2$.

a. Chlorides and Amides.

Cyanogen chloride, chlorcyan, NC−Cl, is obtained by passing chlorine through a solution of mercuric cyanide or a watery solution of hydrocyanic acid:

$$Hg(CN)_2+4Cl=HgCl_2+2NC-Cl;$$
$$HCN+2Cl=HCl+NC-Cl.$$

It forms an oily colorless liquid boiling at 15° and whose vapors are irritating and cause the flow of tears.

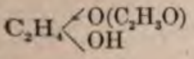
Cyanuric chloride, solid cyanogen chloride, $N_3C_3Cl_3$, is a derivative of triazine (which see), and is formed by keeping cyanogen chloride, also by passing chlorine into anhydrous hydrocyanic acid, in direct sunlight. It forms shining poisonous crystals which melt at 145°.

Cyanamide, $NC-NH_2$, is obtained, as colorless crystals melting at 40° C, by the action of ammonia upon cyanogen chloride. If warmed with dilute sulphuric or nitric acid it combines with 1 molecule of water and is trans-

4. Dihydric Alcohols.

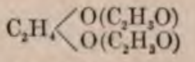
General formula, $C_NN_{2N}(OH)_2$.

HO groups are attached to the alkylenes after the rupture ble bonds of the C atom, we obtain a series of dihydric hich are called *glycols* on account of their sweet taste: glycol, $HO{-}H_2C{-}CH_2{-}OH$ or $C_2H_6O_2$, propylene glycol, $CH_2{-}CH_2{-}OH$, etc. As we have two replaceable hydro- s (hydroxyl groups) in these bodies, it is possible to form two thers of the same alcohol radical, two glycolates of the alkali (p. 343), also two esters of the same acid, etc.:



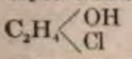
$C_2H_4\begin{cases}O(C_2H_3O)\\OH\end{cases}$

Glycol monacetate.



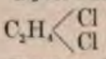
$C_2H_4\begin{cases}O(C_2H_3O)\\O(C_2H_3O)\end{cases}$

Glycol diacetate.



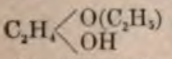
$C_2H_4\begin{cases}OH\\Cl\end{cases}$

Glycol chlorhydrin.



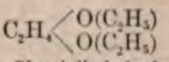
$C_2H_4\begin{cases}Cl\\Cl\end{cases}$

Ethylene chloride.



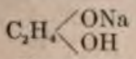
$C_2H_4\begin{cases}O(C_2H_5)\\OH\end{cases}$

Glycol ethyl ether.



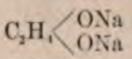
$C_2H_4\begin{cases}O(C_2H_5)\\O(C_2H_5)\end{cases}$

Glycol diethyl ether.



$C_2H_4\begin{cases}ONa\\OH\end{cases}$

Monosodium glycolate.



$C_2H_4\begin{cases}ONa\\ONa\end{cases}$

Disodium glycolate.

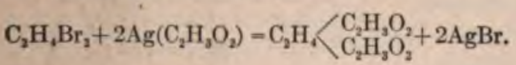
The anhydrides of the glycols or alkylene oxides correspond to the ydrides (ethers) of the monhydric alcohols. As the glycol mole- contains two hydroxyl groups, therefore water can be split off one molecule in the same way as from the dihydroxyl com- nds of the metals:

$$Ca(OH)_2 = CaO + H_2O; \quad \underset{\text{Ethylene glycol.}}{C_2H_4(OH)_2} = \underset{\text{Ethylene oxide.}}{C_2H_4O} + H_2O$$

only glycols known are those with two C atoms or more (p. 331).

ccurrence. They are not found in nature.

reparation. 1. From the ethylene bromides, by heating them silver acetate or potassium acetate:



$$C_2H_4Br_2 + 2Ag(C_2H_3O_2) = C_2H_4\begin{cases}C_2H_3O_2\\C_2H_3O_2\end{cases} + 2AgBr.$$

condary sal . If COS is passed into potassium eth
tain the potassium salt of carbonylethylmonosulphocarbonic ac

$$COS + C_2H_5-OK = KS-CO-OC_2H_5.$$

b. Amido-derivatives.

ike all other organic bibasic acids, carbonic acid forms the sa
les and imides (p. 420); for example,

$CO<\begin{matrix}OH\\OH\end{matrix}$	$CO<\begin{matrix}NH_2\\OH\end{matrix}$	$CO<\begin{matrix}NH_2\\NH_2\end{matrix}$	$CO=NH$
Carbonic acid.	Carbamic acid.	Carbamide.	Carbimide.

Carbamic Acid, $HO-CO-NH_2$, is not known free, but its calcium
occurs in horses' urine and in the urine of man and dogs whe
ge amounts of calcium salts are partaken of. Ammonium car-
mate occurs in commercial ammonium carbonate (p. 218) and is
med by the union of dry ammonia with carbon dioxide, $2NH_3+CO_2=$
$H_2-CO-ONH_4$. It forms a white crystalline mass which in the
resence of water is transformed into ammonium carbonate:

$$H_2N-CO-ONH_4 + H_2O = H_4NO-CO-ONH_4.$$

Carbamic acid ethylester, $H_2N-CO-OC_2H_5$, urethan, forms colorless crystals which are readily soluble.

Carbamide, urea, CN_2H_4O or $H_2N-CO-NH_2$.

Occurrence. It is the chief constituent of human urine (2–3 per cent.) and the urine of mammalia, birds, and amphibians. It occurs to a less extent in the blood, liver, kidneys, lymph, etc., and in uræmia it occurs to a very great extent in all human tissues and fluids.

Formation. 1. Like all amides, by heating the corresponding ammonium salt; e.g., from ammonium carbonate:

$$CO<\begin{matrix}ONH_4\\ONH_4\end{matrix} = CO<\begin{matrix}NH_2\\NH_2\end{matrix} + 2H_2O;$$

also by heating ammonium carbamate:

$$CO<\begin{matrix}NH_2\\ONH_4\end{matrix} = CO<\begin{matrix}NH_2\\NH_2\end{matrix} + H_2O.$$

In both cases this takes place by heating to about 130° in sealed vessels.

2. From carbonyl chloride and ammonia:

$$COCl_2 + 2NH_3 = CO(NH_2)_2 + 2HCl.$$

xcess, the carbon dioxide is absorbed and only
nd the quantity of urea decomposed can be
lume of the gas (Knop-Hüfner method).
id base which combines directly with acids,
nitrate, $CO(NH_2)_2 \cdot HNO_3$, is readily soluble in
insoluble in nitric acid. Urea oxalate,
H_2O, is very slightly soluble in cold water.
detected in concentrated aqueous solution by
the precipitates of both salts exhibiting a
ne form under the microscope.)
nt compound of urea is that with mercuric
n the quantitative estimation (Liebig-Pflüger

ing up to 4 per cent. urea be treated with dilute
tion, we obtain the compound $Hg(NO_3)_2+$
after every addition of the mercuric nitrate we
solution with a soda solution, we obtain, as soon
itated and the slightest excess of mercuric nitrate
of mercuric oxide, because the white precipitate
ot change its color by soda. If a mercuric nitrate
own amount of Hg is treated with a urea solution
loes not turn yellowish red with soda, we can cal-
rea from the volume of the mercuric nitrate solu-

o-urea, $CS(NH_2)_2$. As ammonium cyanate is trans-
carbamide by evaporation, so also is ammonium
converted into its isomer sulphocarbamide on

$-CO-NH_2$; $SCN(NH_4)=NH_2-CS-NH_2$.

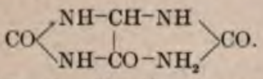
edles which are soluble in water and alcohol and
e directly with acids, forming compound sulpho-
ared from CS_2 and primary amines:

$NH_2 \cdot CH_3 = CS(NH \cdot CH_3)_2 + H_2S$.

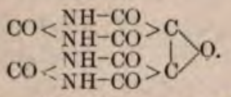
, allyl thio-urea, thiosinamine, $NH_2-CS-NH(C_3H_5)$,
having a leek-like odor, and is prepared from
n of ammonia.

or $NH_2-C(NH)-NH_2$, imido-carbamide, is de-
ch the =O is replaced by the divalent imide

ed by the oxidation of guanine (p. 417, hence fluid of cows, in the horse-chestnut and maple, and forms shining crystals which decompose into urea and allanturic acid (p. 413) by the action of alkalies:



Alloxanthine, $C_8H_4N_4O_7$, the diureide of tatronylic and mesoxalylic acids. It is produced from alloxan by reduction with $SnCl_2$. Its tetramethyl derivative is called amalic acid, and is produced from caffeine (p. 418) by the action of chlorine water:

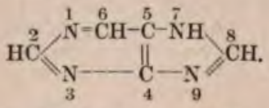


Purpuric acid, imido alloxanthine, $C_8H_4N_4O_6(NH)$, does not occur free; its ammonium salt is called murexid and is used in the detection of uric acid (see 419).

d. Purin Derivatives.

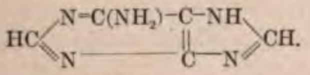
Hypoxanthine, $C_5H_4N_4O$, xanthine, $C_5H_4N_4O_2$, and the diureïde uric acid, $C_5H_4N_4O_3$, contain the tetravalent acid radical trioxyacryl, $-OC-\overset{|}{C}=\overset{|}{C}-$, of the hypothetical trioxyacrylic acid, $HOOC-C(OH)_2=C(OH)_2$; these bodies and their methyl and amido derivatives may be derived better from *purin*, $C_5H_4N_4$, than from urea. Hypoxanthine, xanthine, and their derivatives, adenine and guanin, are also called *xanthine* or *nuclein bases*, as they are cleavage products of the nucleoproteids.

Purin, $C_5H_4N_4$ or

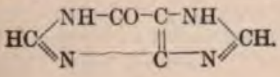


This is a diazindiazole (see Heterocyclic Compounds). The figures given above in the formula serve to designate the constitution of the derivatives. Purin is obtained from uric acid by transforming it into trichlorpurin (p. 419) and replacing the chlorine of this by nascent hydrogen. It forms colorless crystals which are readily soluble and melt at 216°, forming salts with acids and bases. Chlorinated purins serve in the syntheses of its derivatives.

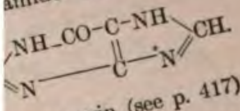
Adenine, $C_5H_3N_4(NH_2)$, 6-amidopurin, occurs in the nucleins, in the spleen, pancreas, tea, etc. It forms colorless needles with 3 mol. H_2O:



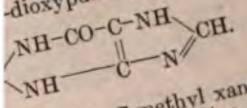
Hypoxanthine, sarcine, $C_5H_4N_4O$, 6-oxypurin (see p. 417):



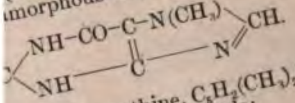
amido hypoxanthine, 2-amido-6-oxypurin



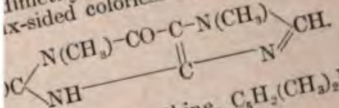
-dioxypurin (see p. 417):



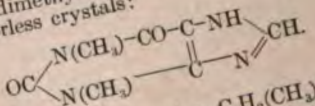
(CH$_3$)N$_4$O$_2$, 7-methyl xanthine, occurs as traces
morphous or crystalline powder:



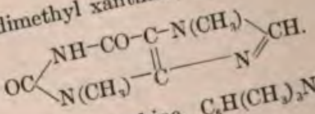
imethyl xanthine, $C_5H_2(CH_3)_2N_4O_2$, occurs as traces
x-sided colorless crystals:



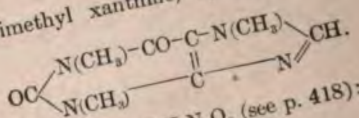
,3-dimethyl xanthine, $C_5H_2(CH_3)_2N_4O_2$, occurs in tea.
olorless crystals:



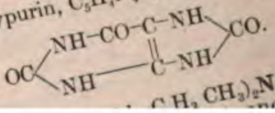
, 3,7-dimethyl xanthine, $C_5H_2(CH_3)_2N_4O_2$ (see p. 418)



1,3,7-trimethyl xanthine, $C_5H(CH_3)_3N_4O_2$, methyl theobro-
):



id, 2,6,8-trioxypurin, $C_5H_4N_4O_3$ (see p. 418):



$C_5H_2 CH_3)_2N_4O_3$, occurs in muscle
nd the juice of the sugar-

Hypoxanthine, sarcine, $C_5H_4N_4O$ (structure, p. 41
always associated with xanthine in the nuclein
of horses or oxen; in many animal tissues
in the spleen, liver, kidneys, brain, pancrea
plants, such as the pumpkin, malt, and lu
young potatoes, etc.

Preparation. 1. By the action of nitrous ac

$$C_5H_5N_5+HNO_2=C_5H_4N_4O+H_2O+$$

2. Ordinarily from meat extracts, whose aqu
by silver nitrate and the precipitate
acid and then allowed to stand, when hy
silver separate out, while xanth

Properties. White crystalline powder w
and which combines with acids and

Guanine, amidohypoxanthine, $C_5H_3N_4O(NH$
in the excrement of snails, cephalop
spleen, liver, lungs, in the young sprou
extent in guano.

Preparation. 1. From Peruvian guano
p. 418).
2. From meat extracts (see Hypoxanth

Properties. It forms colorless crystals
is insoluble in water, alcohol, or e
as well as with bases. On oxidatio
and parabanic acid (oxalyl urea

$$C_5H_5N_5O+3O+H_2O=CH$$

acid converts it into xanthine:

$$C_5H_5N_5O+HNO_2=C$$

Xanthine, $C_5H_4N_4O_2$ (structure,
generally associated with hy

Preparation. 1. Ordinarily f
2. By the action of nitr
p. 419).
3. From uric acid by

Properties. White
and alkalies ar
and caffeine
xanthine gives
ammonia (We

and beautiful blue on the subsequent addition of caustic alkali (mu test, p. 415).

9. Oxalic Acid Series.

General formula $C_NH_{2N-2}O_4$.

Oxalic acid	$C_2H_2O_4$	**Suberic acid**	$C_8H_{14}O_4$
Malonic acid	$C_3H_4O_4$	**Azelaic acid**	$C_9H_{16}O_4$
Succinic acid	$C_4H_6O_4$	**Sebacic acid**	$C_{10}H_{18}O_4$
Pyrotartaric acid	$C_5H_8O_4$	**Brassylic acid**	$C_{11}H_{20}O_4$
Adipic acid	$C_6H_{10}O_4$	**Roccelic acid**	$C_{17}H_{32}O_4$
Pimelic acid	$C_7H_{12}O_4$	etc.	

Properties. The dihydric, bibasic acids of the glycols are c the acids of the oxalic acid series. They are crystalline solids, volatile without decomposition, and generally soluble in water. they contain two hydroxyl groups they are diatomic, and as contain two carboxyl groups they are bibasic and form neutral acid salts as well as esters:

$HOOC-COO(C_2H_5)$ Primary or acid ester. $(C_2H_5)OOC-COO(C_2H)_5$ Secondary or neutral ester.

The amide derivatives are similar in properties and metho formation to the amides of the monobasic acids. On account of presence of the two carboxyl groups we have besides the real am (the diamides) also acid amides or amine acids:

$(H_2N)OC-CO(NH_2)$ Oxamide. $(H_2N)OC-COOH$ Oxamic acid.

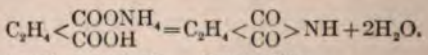
On replacing two H atoms in a molecule of ammonia by a diva acid radical we obtain imides, $C_2H_4<\genfrac{}{}{0pt}{}{CO}{CO}>NH$, succinic acid imid

These derivatives may also be prepared from the acid and neu ammonium salts by removing water:
Acid ammonium salts minus H_2O = *amic acids:*

$$HOOC-COO-(NH_4)=HOOC-CO-NH_2+H_2O.$$

Acid ammonium oxalate. Oxamic acid.

Acid ammonium salts minus $2H_2O$ = *imides:*



$$C_2H_4<\genfrac{}{}{0pt}{}{COONH_4}{COOH}=C_2H_4<\genfrac{}{}{0pt}{}{CO}{CO}>NH+2H_2O.$$

Acid ammonium succinate. Succinimide.

Neutral ammonium salts minus $2H_2O$ = *amides:*

$$H_4N{-}OOC{-}COO{-}NH_4 = NH_2{-}OC{-}CO{-}NH_2 + 2H_2O.$$

Ammonium oxalate. Oxamide.

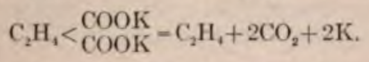
Neutral ammonium salts minus $4H_2O$ = *nitriles:*

$$H_4N{-}OOC{-}COO{-}NH_4 = NC{-}CN + 4H_2O \text{ (p. 423).}$$

Anhydrides may be formed similarly to the oxyfatty acids even th one molecule (see Succinic Acid), when the carboxyls occur ited to different carbon atoms. If the carboxyls are united to one tom, then on heating fatty acids are obtained and at the same time $_2$ is split off: $HOOC{-}CH_2{-}COOH = CH_3{-}COOH + CO_2$.

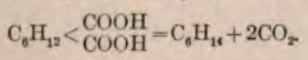
With the exception of oxalic acid all the acids of this series may considered as alkylene dicarbonic acids, which coincides with the thods of formation and with their decomposition.

If the potassium salts are decomposed by the electric current obtain alkylenes, carbon dioxide, and potassium:



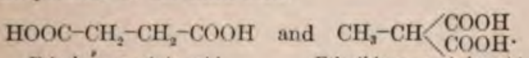
$$C_2H_4<^{COOK}_{COOK} = C_2H_4 + 2CO_2 + 2K.$$

When heated with alkali hydroxides they decompose into ethanes d carbon dioxide; thus suberic acid yields hexane:



$$C_6H_{12}<^{COOH}_{COOH} = C_6H_{14} + 2CO_2.$$

The possible isomers of the dibasic acids correspond to the isomers the alkylenes. The two carboxyl groups may be united to two different ms or to one carbon atom. No isomers are possible of the first two ds—oxalic acid, $HOOC{-}COOH$, and malonic acid, $HOOC{-}CH_2{-}COOH$—ile two are possible of the third acid:

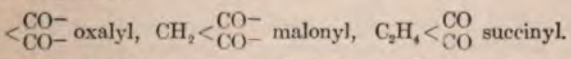


$$HOOC{-}CH_2{-}CH_2{-}COOH \quad \text{and} \quad CH_3{-}CH<^{COOH}_{COOH}.$$

Ethylene succinic acid. Ethylidene succinic acid.

There are four isomers possible of the fourth member, $C_3H_6(COOH)_2$, c. The isomers, which have both carboxyl groups united to one C atom, y be said to be derived from malonic acid (p. 423) and their structure called the malonic acid structure.

We call the divalent acid residues united with the two hydroxyls the id radicals (p. 336):



$$<^{CO-}_{CO-} \text{ oxalyl,} \quad CH_2<^{CO-}_{CO-} \text{ malonyl,} \quad C_2H_4<^{CO}_{CO} \text{ succinyl.}$$

Preparation. 1. If the halogen alkylenes are heated with potassium anide we obtain alkylene cyanides, which yield the corresponding acid boiling with acids or caustic alkalies (p. 346, 2):

$$CN-CH_2-CH_2-CN+4H_2O=HOOC-CH_2-CH_2-COOH+2NH_3;$$

Ethylene cyanide. Ethylene succinic acid.

$$CN-CH(CN)-CH_3+4H_2O=HOOC-CH(COOH)-CH_3+2NH_3.$$

Ethylidene cyanide. Ethylidene succinic acid.

2. The monohalogen fatty acids are transformed into the cyanfatty acids and the cyanogen group is converted into the carboxyl group by boiling with acids or caustic alkalies:

$$HOOC-CH_2-CH_2-CN+2H_2O=HOOC-CH_2-CH_2-COOH+NH_3;$$

β-Cyanpropionic acid. Ethylene succinic acid.

$$HOOC-CH(CN)-CH_3+2H_2O=HOOC-CH(COOH)-CH_3+NH_3.$$

α-Cyanpropionic acid. Ethylidene succinic acid.

3. By the oxidation of the acids of the fatty acid and oleic acid series as well as of neutral fats by means of HNO_3.

4. By the oxidation of the normal glycols and oxyfatty acids (mentioned on pp. 400, 402).

5. The homologues of oxalic acid are produced from malonic acid ethyl-ester in a similar manner to acetic acid from aceto-acetic ester.

Oxalic Acid, $C_2H_2O_4$ or $HOOC-COOH$. *Occurrence.* It exists combined as acid potassium salt in many plants, such as in the varieties of Runex and Oxalis, from whose juice oxalic acid used to be obtaind by evaporation. It also occurs in many plants as calcium oxalate, partly in solution and partly as crystals. Oxalic acid also occurs as calcium salt in the animal kingdom, especially in normal and pathological urine, as urinary sediment, in the caterpillar excrement, as vesicle calculi (mulberry calculus), and as potassium oxalate in many organs.

Formation. 1. By passing CO_2 over fused sodium we obtain sodium oxalate: $2CO_2+2Na=C_2Na_2O_4$.

2. From fats, carbohydrates (sugar, starch, gums, cellulose), and many other organic bodies by oxidation with nitric acid. On fusing these bodies with caustic alkalies we obtain alkali oxalates.

Preparation. 1. By fusing sawdust (cellulose, $C_6H_{10}O_5$) with alkali hydroxide at 250° to 300° (p. 323):

$$C_6H_{10}O_5+H_2O+6NaOH=3C_2Na_2O_4+18H.$$

2. By heating alkali formates: $2H-COONa=NaOOC-COONa+2H$.

The alkali oxalate thus obtained is dissolved in water and the solution mixed with calcium hydroxide (milk of lime) and the insoluble calcium oxalate which separates out treated with sulphuric acid, when insoluble calcium sulphate precipitates and a solution of oxalic acid is obtained.

onsists of rhombic crystals which
ution is dextrorotatory at ordinary tempera
, while at higher temperatures it is lævorotat
dextrorotatory and the alkaline solution læv

HOOC–$C_2H_3(NH_2)$–CO–(NH_2), amido-succ
mide of amidosuccinic acid, occurs in the p
s, licorice, marsh-mallow, oyster-plant, and in
specially in the sprouts. It crystallizes with 1
ss prisms from the pressed juice of these plants
These crystals are tasteless and lævorotatory. It
in water and insoluble in alcohol and ether and form
as well as with bases.
with water, but quicker with acids or alkalies, it splits into

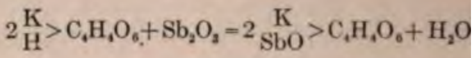
$$) < \genfrac{}{}{0pt}{}{CO(NH_2)}{COOH} + H_2O = C_2H_3(NH_2) < \genfrac{}{}{0pt}{}{COOH}{COOH} + NH_3.$$

nverts it into malic acid:

$$) < \genfrac{}{}{0pt}{}{CO(NH_2)}{COOH} + 2HNO_2 = C_2H_3(OH) < \genfrac{}{}{0pt}{}{COOH}{COOH} + 2H_2O + 4N.$$

paragine, which has a sweet taste, is obtained from the
ts and inactive asparagine is prepared synthetically.
c acid, CH–CH$(COOH)_2$, ethylidene dicarbonic acid, is ob-
he α-cyanpropionic acid (p. 422, 2) and forms colorless crystals,
re soluble in water than the ordinary succinic acid. It melts
nd decomposes on further heating into carbon dioxide and
d.
ric acid, $C_5H_8O_4$, or HOOC–C_3H_6–COOH. Four isomers are
known, according to the structural theory, and of these we
n:
pyrotartaric acid, CH_3–CH(COOH)–CH_2–COOH, or methyl
is produced on the dry distillation of tartaric acid (p. 428).
12°, and is inactive and can be split into the two optically
ations.
rotartaric acid, HOOC–H_2C–CH_2–CH_2–COOH, or glutaric
ed synthetically and melts at 97° C.
mal pyrotartaric acid, amido glutaric acid, glutamic acid,
$H_2)$–CH_2–CH_2–COOH, occurs with aspartic acid in many
eet-root molasses, and is obtained with other amido acids
teins (which see) with dilute sulphuric acid, etc. It forms
s which are dextrorotatory in aqueous solution. The
ation is also known and the lævorotatory modification
from *this* by the action of molds.

emetic. In this compound the H atom of one carbox by the monovalent group antimonyl, SbO (p. 180). It by boiling potassium acid tartrate, antimony oxide, filtering and evaporating the solution until white, sweet obtained which are soluble in 17 parts water and vomiting:



$$2\,{}^{K}_{H}{>}C_4H_4O_6 + Sb_2O_3 = 2\,{}^{K}_{SbO}{>}C_4H_4O_6 + H_2O$$

Calcium tartrate, $C_4H_4CaO_6 + 4H_2O$, precipitates from ne solutions by the addition of calcium chloride as a white cryst which is soluble in dilute acids. Cold solutions of alkalies al but on boiling the solution it precipitates again (separatio and citric acids).

Aluminium aceto-tartrate, $Al_2(C_2H_3O_2)_2(C_4H_4O_6)(OH)_2$, colorless gummy masses which are soluble in water.

Borax-tartar, $KNaC_4H_4O_6 + 2K(Bo)C_4H_4O_6$, is obtaine ing borax and cream of tartar in water and evaporating to

Citric acid, $C_6H_8O_7$ or $CH_2(COOH)-C(OH)(COOH)-$ oxypropantricarbonic acid, on account of its occurrence on heating, etc., will be treated of here.

Occurrence. Free in the lemon, currant, cranberry, ar fruits, in the beet-root, and to a slight extent in milk.

Preparation. 1. From lemon-juice by neutralizing w heating to boiling, when calcium citrate (p. 431) se This is decomposed by dilute sulphuric acid, the calci the chlorine is replaced by CN and if this product is heated again with HCl citric acid is obtained:

$$CH_2(CN)-C(OH)(COOH)-CH_2(CN)+4H_2O=$$
$$CH_2(COOH)-C(OH)(COOH)-CH_2(COOH)+2NH_3.$$

Properties. Large colorless rhombic prisms with 1 mol. H_2O, which melt at 100° and lose their water of crystallization at 150°. On further heating it forms aconitic acid, $C_6H_6O_6$, then itaconic acid and mesaconic acid, $C_5H_6O_4$ (see below). Citric acid is readily soluble in water and alcohol. It is tetravalent and tribasic and hence forms three series of salts (*citrates*) and esters. On oxidation it yields oxalic acid, acetic acid, and acetone.

Calcium citrate, $Ca_3(C_6H_5O_7)_2+4H_2O$, is not readily soluble in cold water, but insoluble in hot water; hence a cold saturated solution precipitates completely on boiling (detection of citric acid).

Magnesium citrate, $Mg_3(C_6H_5R_7)_2+14H_2O$, mixed with citric acid, sodium bicarbonate and sugar, forms the ordinary effervescent magnesia or magnesii citras effervescens.

Silver citrate, itrol, $Ag_3C_6H_5O_7$, is a colorless powder.

Ferric citrate, $Fe(C_6H_5O_7)+3H_2O$, is obtained by dissolving ferric hydroxide in citric acid and evaporating, when an amorphous brown mass soluble in water is obtained. Iron-ammonium citrate, $2Fe(C_6H_5O_7)+(NH_4)_2C_6H_6O_7+2H_2O$, forms amorphous brownish-red masses soluble in water.

Tricarballylic acid, propantricarbonic acid, $C_6H_8O_6$ or $C_3H_5(COOH)_3$, occurs in unripe beet-root and is prepared from aconitic acid (see below) by the action of nascent hydrogen or by heating citric acid with HI.

Aconitic acid, equisetic acid, $C_6H_6O_6$ or $C_3H_3(COOH)_3$. This tribasic acid occurs in Aconitum napellus, Equisetum fluviatile, in sugar-cane, and in the sugar-beet, and is produced by heating citric acid to 175°:

$$C_3H_4(OH)(COOH)_3=C_3H_3(COOH)_3+H_2O.$$

Itaconic acid, methylene succinic acid, $C_5H_6O_4$ or $CH_2=C_2H_2(COOH)_2$, and its isomer.

Citraconic acid, methylmaleïc acid, $C_5H_6O_4$, are obtained by heating citric or aconitic acid above 175°.

Mesaconic acid, methylfumaric acid, $HOOC-(CH_3)C=CH-COOH$ or $C_5H_6O_4$, a stereoisomer of citraconic acid is prepared by heating itaconic or citraconic acids with water to 200°.

COMPOUNDS OF TRIVALENT ALCOHOL RADICALS.

1. Trivalent Alcohol Radicals.

General formula C_NH_{2N-1}.

These, like all radicals with uneven valence, do not exist free; They are called methenyl, ethenyl, propenyl, etc., or glyceryl, butenyl, crotonyl, etc. The trivalent compounds are derived from the saturated hydrocarbons in a manner similar to that of the mono- and divalent compounds in that three atoms are replaced by other atoms or by atomic groups. The relationship of these compounds to each other is simply as follows:

Propyl alcohol,	C_3H_8O.	Propionic acid,	$C_3H_6O_2$.
Propylene alcohol,	$C_3H_8O_2$.	Lactic acid,	$C_3H_6O_3$.
Propenyl alcohol,	$C_3H_8O_3$.	Glyceric acid,	$C_3H_6O_4$.

2. Trihydric Alcohols.

General formula $C_NH_{2N-1}(OH)_3$.

The properties which the glycols show is also found in the trihydric and polyhydric alcohols, and these become more and more pronounced as the number of hydroxyl groups increases. Thus from glycerine on oxidation we obtain a trihydric, monobasic acid, as well as a trihydric, dibasic acid; also aldehyde alcohols, ketone alcohols, etc. (p. 337). We do not know of any trihydric alcohols containing less than three C atoms (p. 331).

Glycerine, $C_3H_5(OH)_3$ or $CH_2(OH)-CH(OH)-CH_2(OH)$, Propenyl Alcohol, Glycerol. *Occurrence.* It is the only trihydric alcohol found in nature and occurs as glycerine acetate (triacetin), $C_3H_5(C_2H_3O_2)_3$, in ethereal oils of the spindle-tree, and forms esters with the higher fatty acids and oleic acid, which constitute the animal and vegetable fats. It is produced to a slight extent in alcoholic fermentation and hence exists in beer and wine.

Preparation. 1. As a by-product in the manufacture of soaps and plasters, where the fats (fatty acid esters of glycerine) are decomposed by alkalies or lead hydroxide in a manner similar to other esters (p. 357, 2). It is formed, for example, when fats are boiled with lead hydroxide, producing an insoluble lead salt of the fatty acid and glycerine:

$$\underset{\text{Tristearin.}}{2C_3H_5(C_{18}H_{35}O_2)_3} + 3Pb(OH)_2 = 2C_3H_5(OH)_3 + 3Pb(C_{18}H_{35}O_2)_2.$$

2. As a by-product in the manufacture of stearin candles (p. 4
where fats are treated with superheated steam or warmed with

centrated sulphuric acid to 120° C., when the fat takes up water and splits into glycerine and the fatty acids which separate out:

$$\underset{\text{Tristearin.}}{C_3H_5(C_{18}H_{35}O_2)_3} + 3H_2O = \underset{\text{Glycerine.}}{C_3H_5(OH)_3} + \underset{\text{Stearic acid.}}{3C_{18}H_{36}O_2}.$$

The solution of glycerine thus obtained according to methods 1 or 2 (after neutralization or removal of dissolved lead oxide by H_2S) is carefully concentrated by evaporation, the salts which separate removed by filtration, and the crude glycerine thus obtained purified by distillation with superheated steam.

Synthetically. Propenyl bromide with silver acetate yields glycerine acetic acid ester, which is saponified by bases:

$$C_3H_5Br_3 + 3AgC_2H_3O_2 = C_3H_5(C_2H_3O_2)_3 + 3AgBr;$$
$$C_3H_5(C_2H_3O_2)_3 + 3KOH = C_3H_5(OH)_3 + 3KC_2H_3O_2.$$

Or propenyl chloride is heated with water to 170°:

$$C_3H_5Cl_3 + 3HOH = C_3H_5(OH)_3 + 3HCl.$$

Properties. Thick, colorless, sweet (hence the name) liquid having a specific gravity of 1.27, and when free from water it solidifies to a white crystalline mass at 0° C. It distils without decomposition at 290° C., and is soluble in water and alcohol but insoluble in ether and fatty oils. It dissolves the alkalies and alkaline earths and many metallic oxides, forming compounds similar to the alcoholates. With dehydrating agents it gives acrolein, C_3H_4O (p. 439), and when carefully oxidized it gives, according to the conditions, aldehydes and acids or mixed compounds. As glycerine contains three hydroxyl groups, it forms three series of esters (the *glycerides*) and mixed ethers.

3. Derivatives of Trivalent Alcohols.

Glyceric aldehyde, $C_3H_6O_3$ or $CHO-CH(OH)-CH_2OH$, is an aldehyde alcohol and forms colorless sweet crystals.

Dioxyacetone, $CH_2\cdot OH-CO-CH_2OH$, the isomeric ketone alcohol, forms sweet crystals.

Both compounds are obtained as a mixture (called *glycerose*) by the careful oxidation of glycerine. They readily unite, forming inactive lævulose, $C_6H_{12}O_6$, also called α-acrose. Glyceric aldehyde and dioxyacetone are true sugars (carbohydrates) according to their constitution (p. 402), and can only be obtained pure in an indirect manner.

Glyceric acid, dioxypropionic acid, $C_3H_6O_4$ or $CH_2\cdot OH-CH\cdot OH-COOH$, is produced on the oxidation of glycerine by dilute nitric acid. It forms an inactive sirup which is readily soluble in water and alcohol. It is converted into the lævorotatory modification by Penicillium glaucum, and on being heated it splits into water and pyroracemic acid:

$$C_3H_6O_4 = H_2O + C_3H_4O_3.$$

It is a wax-like neutral solid, readily soluble in alcohol and ether, readily decomposable, and combines with acids and alkalies.

On boiling with acids or baryta-water they decompose into choline, $(HO \cdot C_2H_4)N(CH_3)_3(OH)$, glycero-phosphoric acid, palmitic and stearic acids, or oleic acid, $C_{18}H_{34}O_2$, and therefore the following formula can be given as their structure:

$$(C_NH_{2N-1}O_2)_2 = C_3H_5 - HPO_4 - C_2H_4 \cdot N(CH_3)_3 \cdot OH.$$

Glyceryl palmitate, palmitin, $C_3H_5(C_{16}H_{31}O_2)_3$, crystallizes in shining leaves which melt at 63° C.

Glyceryl stearate, stearin, $C_3H_5(C_{18}H_{35}O_2)_3$, also crystallizes in shining leaves and melts at 67° C.

Glyceryl oleate, olein, $C_3H_5(C_{18}H_{33}O_2)_3$, forms an oily liquid (p. 440) which solidifies at $-6°$ C.

These three esters may be obtained by heating glycerine with the respective acids and mixed together form the chief constituent of all animal and vegetable fats, which are divided into three classes, namely, tallows (solid), butter and lard (semi-solid), and oils (liquids). Oils contain chiefly olein, while the tallows contain stearin chiefly.

The Fats in General. The fats are obtained by pressure or by extraction with ether, carbon disulphide, etc. Butter is prepared by violently beating milk, when the fat globules conglomerate. Artificial butter or margarine is obtained by trying out animal fat and allowing it to cool, and then exposing it to pressure, which frees the fat of stearin and yields an oil (oleomargarine-oil). This oil, which is a mixture of olein and palmitin is strongly shaken with warm milk in a method similar to the manufacture of butter, when the artificial butter separates. This is colored yellow and treated with butyric acid esters.

The fats when pure are colorless, odorless, and tasteless neutral bodies insoluble in water, not readily soluble in alcohol, but readily soluble in ether and carbon disulphide. They are lighter than water and produce a transparent stain when applied to paper which does not disappear on warming (differing from the ethereal oils). They can be heated to 300° C. without suffering any change, but at higher temperatures they decompose, yielding various products having an unpleasant odor, chief amongst which is acrolein.

Many fats when exposed to the air are gradually converted into a hard transparent mass. These are called drying oils; for instance, hemp-seed oil, croton-oil, linseed-oil, poppy-oil, nut-oil, which consist chiefly of the glycerides of linoleic acid, $C_{18}H_{32}O_2$ (p. 445), as well as castor-oil. These unsaturated glycerides become solid on absorbing oxygen.

The other fats do not change when pure, but as they generally consist of mixtures, especially with proteids, they gradually suffer decomposition becoming disagreeable in taste and smell and having an acid reaction, i.e., they become rancid. This depends upon the setting free of fatty acids

Cacao-butter, obtained from the seeds of the Theobroma
pressure, consists of olein, palmitin, stearin, and theobromic aci
(p. 377).

Nutmeg-butter, obtained from the nutmeg by pressure,
myristicin, olein, and ethereal oils.

Cocoanut-oil, the fat of the seed-kernel of the Cocos nucife
of laurin, myristin, and palmitin.

Liquid Fats. Olive-oil is obtained from the olives by pressu
oil treated with 6 per cent. oleic acid is used in medicine unde
lipanin.

Almond-oil is obtained by pressing the sweet or bitter almo

Poppy-oil is produced by pressing the poppy-seed.

Linseed-oil, from the flaxseed.

Laurel-oil, obtained from the fresh ripe laurel by pressure,
laurin.

Rape-seed oil, from the seeds of the rape.

Castor-oil, from the seeds of the Ricinus communis, conta
glycerids of ricinoleic acid.

Croton-oil, from the seeds of the Croton tiglium, also co
poisonous glyceride of the little-known crotonolic acid, but
tonic acid (p. 440).

Cod-liver oil, from the fresh livers of the codfish by gently he

Sesame oil, from the seeds of the Sesamum orientale, is add
ficial butter in Germany in order to be able to detect the same
Its bromine and iodine addition products are used in medicine as
and iodipin.

Soaps. On heating glycerides with alkali hydroxides
strong bases they are decomposed in a manner simila
esters of the mono- and dihydric alcohols, i.e., they decom
salts of the acids contained in the glycerides and into
(p. 432). The decomposition of the esters, i.e., the fats,

the soaps are in part decomposed into free alkali and acid salts of the fatty acids. The action of soaps in washing depends upon this property, as the alkali set free and the acid salt of the fatty acids which form the froth readily remove the fat in the form of an emulsion, and the froth envelops the dirt and removes it.

The other salts of the above-mentioned fatty acids are mostly soluble in alcohol but insoluble in water, hence water rich in calcium salts forms a precipitate with soap solutions forming insoluble calcium salts of the fatty acids which is the reason why hard waters are not suitable for washing purposes.

Official soap is pure sodium soap; Green soap is pure potassium soap, whose alcoholic solution is called spiritus saponatus.

Soap liniment, opodeldoc, is a gelatinous mixture of alcohol, sodium soap, camphor, ammonia, and ethereal oils; liquid opodeldoc is a solution of potassium soaps and camphor in alcohol. Ammonia liniment is a mixture of fatty oils with ammonia, and in the presence of camphor-oil it is called camphorated ammonia liniment.

Plasters. The lead salts of the fatty acids are called lead plasters. These are obtained directly by boiling fats with lead oxide and water (p. 432).

On mixing lead plaster with different substances we obtain mercurial plaster, soap plaster, adhesive plaster, etc. The tough mixtures of resins, wax, and oils with active bodies which are used externally are also called plasters. These differ from the salves only in their consistency.

Salves are the semi-plastic mixtures of fats or oils with wax, resin, etc., which have either solid bodies as powders or solutions mixed therewith.

Emulsions. If water contains bodies, such as plant mucilage, albumin, gums, etc., in solution, they give a mucilaginous character and greater viscosity to the liquid If oils are thoroughly mixed with such liquids, they remain suspended as very small globules and the liquid retains a milky appearance. Such mixtures are called emulsions.

4. Monohydric Compounds of Trivalent Alcohol Radicals.

Trihydric alcohol radicals may also appear monovalent, but not free, and form unsaturated compounds which have the property, like all other unsaturated compounds, of readily taking up 2 atoms of H, Br, etc., and being converted into saturated compounds. The radical C_2H_3 or $CH_2{=}CH{-}$ is called vinyl, C_3H_5 or $CH_2{=}CH{-}CH_2{-}$ is called allyl, etc.

a. Alcohols, etc.

Vinyl alcohol, $C_2H_3{-}OH$ or $CH_2{=}CH{\cdot}OH$, occurs in commercial ether and is very unstable.

Vinyl sulphide, $C_2H_3{-}S{-}C_2H_3$, found in the ethereal oil of garlic, is a colorless liquid having a garlic-like odor and boils at 101°.

acid, $C_6H_{10}O_8$, stereoisomer of saccharic acid, is obtained on the of dulcite, galactose, plant mucilages, and certain varieties of itric acid. It forms a white crystalline powder nearly insoluble which on further oxidation yields racemic acid, $C_4H_6O_6$. It is inactive and does not split into active modifications.

POUNDS OF HEPTAVALENT AND HIGHER ALCOHOL RADICALS.

1. Alcohol Radicals.

w of these with even valence are known; e.g., diacetylene, C_4H_4, opargyl, and dimethyl acetylene, C_6H_6, both isomers of benzene.

2. Alcohols and their Derivatives.

seït, $C_7H_{16}O_7$ or $C_7H_9(OH)_7$, is contained in the fruit of the Laurus It forms colorless crystals which melt at 188°.

emite, $C_7H_{16}O_7$, found in the Lactarius volemus, forms colorless rotatory needles which melt at 150°.

lemose, $C_7H_{14}O_7$, is the aldehyde of volemite.

ucoheptite, $C_7H_{16}O_7$ or $C_7H_9(OH)_7$, glucooctite, $C_8H_{18}O_8$ or $C_8H_{10}(OH)_8$ nonite, $C_9H_{20}O_9$ or $C_9H_{11}(OH)_9$. These alcohols form colorless crysand are produced by the action of nascent hydrogen upon their alde- alcohols

Glucoheptose, $C_7H_{14}O_7$, glucooctose, $C_8H_{16}O_8$, glucononose, $C_9H_{18}O_9$, synthetically prepared from the hexoses $C_6H_{12}O_6$ (p. 451, 4) and yield Glucoheptonic acid, $C_7H_{14}O_8$, glucooctonic acid, $C_8H_{16}O_9$, and gluconic acid, $C_9H_{18}O_{10}$, on oxidation. They may also be prepared from e glucoses, $C_6H_{12}O_6$, by the addition of hydrocyanic acid, as mentioned n p. 451, 4.

CARBOHYDRATES.

The name carbohdyrate depends upon the fact that all these compounds contain hydrogen and oxygen in the same proportion as they exist in water, but this proportion also exists in many other compounds, hence it is not characteristic of the carbohydrates.

In the broad sense the term carbohydrates is applied to all aldehyde alcohols (*aldoses*) and ketone alcohols (*ketoses*) of the polyhydric alcohols which contain a HO group attached to the C atoms neighboring the aldehyde or ketone groups, as well as their anhydride-like condensation products.

These compounds may be considered in connection with their corresponding polyhydric alcohols, and this plan has been adopted in connection with the carbohydrates containing less than six atoms of carbon. According to the number of C atoms the carbohydrates are now also called *bioses* ($C_2H_4O_2$, p. 402), *trioses* ($C_3H_6O_3$, p. 433), *tetroses* indifferent, i.e., they are neither acids nor bases. On decompose into bodies of simpler constitution and leave esidue. On oxidation they are transformed into hexon)—respectively saccharic acid, mannosaccharic acid, or p. 446)—and on stronger oxidation (fusion with caustic , they all yield oxalic acid. On boiling with dilute acids d polysaccharides take up H_2O (see Hydrolysis, p. 87) and into monosaccharides, and this transformation may also about by different enzymes (which see). With nitric rm, according to the temperature, etc., either nitrates zed to simpler compounds (p. 322). On heating with mineral acids they yield levulinic acid and humus

carbohydrates with six or one with nine C atoms readily p cleavage by means of organized ferments which we call (p. 325). The chief products produced in this cleavage l, lactic acid or butyric acid, according to the variety of Each ferment can only split a compound of a certain tion (p. 303); thus yeast can only ferment dextrorotatory charides and lævorotatory lævolose, while the disaccharides converted into the fermentable monosaccharides by the es of the yeast. Many carbohydrates dissolve metallic oxides orm saccharates corresponding to the alcoholates (p. 343). The ogen of the OH groups may also be replaced by organic acids, hol radicals, etc. The latter compounds are widely distributed the plants and are called *glucosides* (which see). The glucosides e split into their components by the action of acids, alkalies, and rments, at the same time taking up water. Similar compounds to $C_6H_{11}O_6(CH_3)$ may also be obtained synthetically.

Preparation. Only the monosaccharides and those carbohydrates closely related thereto, but not found in nature, containing 2–9 atoms of carbon, as well as the disaccharides maltose and isomaltose, have been obtained synthetically.

The discovery of E. Fischer, that phenylhydrazin forms insoluble compounds called *osazones* with the above-mentioned carbohydrates, has made it possible to precipitate and identify the artificially obtained varieties of sugars prepared according to the methods to be described. The separation of the sugars from the accompanying by-products and is produced, accompanied with *d*-glucose, from milk-sugar as well as from dextrorotatory varieties of gums on warming with dilute acids. It is more dextrorotatory than *d*-glucose and is insoluble in alcohol. With nascent hydrogen it yields inactive dulcite, and on oxidation galactonic acid, $C_6H_{12}O_7$, and then mucic acid, $C_6H_{10}O_8$, are produced.

l-**Sorbinose,** sorbin, sorbose, is a ketose stereoisomeric with lævulose, and occurs in the juice of the mountain-ash when it has stood for a long time. It forms colorless crystals whose solutions reduce alkaline copper solutions, but is not fermentable with yeast. It is not changed on boiling with acids and yields trioxyglutaric acid, $C_5H_8O_7$ (p. 425), and with nascent hydrogen it is converted into *d*-sorbite, $C_6H_{14}O_6$ (p. 446).

d-**Mannose,** seminose, a stereoisomer of *d*-glucose, is obtained with *d*-lævulose on the careful oxidation of mannite as well as by boiling the carbohydrate *seminin*, occurring in the earth-nut, with dilute acids. It yields mannonic acid, $C_6H_{12}O_7$ (p. 446), on oxidation and mannite (p. 445) on reduction with nascent hydrogen.

2. Disaccharides, $C_{12}H_{22}O_{11}$.

Saccharose, Lactose, Maltose, Mycose, Melebiose, Isomaltose.

The bodies of this group are also called *saccharoses* or *bioses* (p. 448) and contain 8 hydroxyl groups. They are anhydrides of two generally different monosaccharides (hence the name disaccharides) and decompose on heating with dilute acids into monosaccharides, at the same time taking up one molecule H_2O (by hydrolysis):

$$C_{12}H_{22}O_{11}+H_2O=C_6H_{12}O_6+C_6H_{12}O_6.$$

Saccharose, cane-sugar, beet-root sugar, is the anhydride of *d*-glucose and *l*-lævulose. *Occurrence.* In the juice of many plants, especially in the sugar-cane (to 18 per cent.) and the sugar-beet (to 20 per cent.), from which it is chiefly obtained by evaporation. It is principally found in the stem or the roots of the plants, while glucose and lævulose occur to the greatest extent in the fruits.

Preparation. The juice from the sugar-cane or the sugar-beet is heated to boiling with milk of lime (calcium hydroxide), whereby the plant acids are neutralized (p. 454) and the proteids are coagulated and separate as a scum. At the same time a part of the calcium oxide forms with the sugar a soluble calcium saccharate, $C_{12}H_{22}O_{11}+CaO$. The juice is now treated with carbon dioxide, when a large part of the lime is precipitated as calcium carbonate and at the same time a considerable amount of contamination is precipitated out. After the separation of the precipitate the hot juice is filtered through bone-black, which removes the coloring matters and some contained lime and a part of the salts. The filtrate is evaporated to a sirupy consistency in vacuum-pans, when on cooling the cane-sugar crystallizes out. The sirupy, brown mother-liquor, ***molasses***, contains still about 50 per cent. of sugar, which is prevented from crystallizing by the contained salts and organic substances (about 30 per cent.).

Lactose, milk-sugar, lactobiose, is the anhydride of *d*-glucose and *d*-galactose.

Occurrence. In milk, amniotic fluid, in certain pathological secretions, in the urine of sucking animals.

Preparation. Milk which has been freed from casein and fat (the whey) is evaporated to crystallization and the milk-sugar thus obtained purified by recrystallization.

Properties. It forms crystalline masses with 1 mol. H_2O, or a crystalline powder which dissolves in 7 parts cold water and 1 part boiling water, producing a faintly sweet, dextrorotatory, not sirupy solution which shows birotation (p. 452). Lactose is nearly insoluble in dilute alcohol (used in detecting admixture with cane-sugar).

On boiling with dilute acids lactose is converted into a mixture of *d*-galactose and *d*-glucose; by nascent hydrogen it is transformed into mannite and dulcite. It does not ferment with pure yeast, although it readily undergoes lactic-acid fermentation by the action of certain fungi, especially in milk. It undergoes alcoholic fermentation by the kephir and tyrocola fungus (p. 325). On warming with nitric acid it is oxidized to mucic acid, and on boiling with HNO_3 oxalic acid is obtained. It is not decomposed by cold concentrated sulphuric acid. It reduces an ammoniacal silver solution even in the cold, but an alkaline copper solution is only reduced on heating (differing from glucose). On boiling for a long time with dilute H_2SO_4 levulinic acid is produced (p. 371). On heating to 180° it is converted into lactocaramel (p. 454).

Maltose, malt-sugar, maltobiose, is the anhydride of *d*-glucose. It is found in the contents of the small intestine, and is the sugar formed besides dextrins by the action of the enzyme diastase (malt) upon starch:

$$3C_6H_{10}O_5+H_2O=\underset{\text{Maltose.}}{C_{12}H_{22}O_{11}}+\underset{\text{Dextrin.}}{C_6H_{10}O_5}.$$

It can be synthetically prepared from *d*-glucose. It crystallizes with 1 mol. H_2O as hard white masses which consist of needles. It has a greater dextrorotatory action and is less soluble in alcohol than dextrose, and is split into 2 mol. *d*-glucose by boiling with dilute H_2SO_4, as well as by the action of the enzyme *maltase*. Maltose reduces alkaline copper solutions even in the cold, but to a less degree than dextrose. It readily ferments with yeast, as the enzyme maltase of the yeast first splits it into fermentable *d*-glucose.

Melibiose, the anhydride of *d*-glucose and *d*-galactose, is obtained, besides *d*-lævulose, in the inversion of melitriose and is stereoisomeric with milk-sugar.

Isomaltose is prepared synthetically from *d*-glucose, and is produced with maltose by the action of diastase upon starch. It has a weaker reducing power than maltose, but is not fermentable.

Mycose, trehalose, is found in certain fungi, in ergot, in the Manna trehala.

One gram guncotton yields 860 c.c. explosion-gases (p. 207), w
expand to 7800 c.c. the moment they are set free by the heat generat

Collodium cotton, colloxylin, cellulose nitrate, $C_6H_9O_4(NO_2)$, and *cell*
dinitrate, $C_6H_8O_3(NO_2)_2$, are formed by the action of less concentr
nitric acid, are not explosive, and are soluble in alcohol-ether mix
forming collodium.

Collodium leaves the colloxylin, on evaporation, as a transparent
(celloidin) Collodium cantharidatum contains the ethereal extrac
the Spanish-fly. Collodium elasticum contains some castor-oil and
pentine. Zapon varnish is a solution of collodium cotton in aceton
amyl acetate. Celluloid, the substitute for hard rubber, is collo
cotton impregnated with camphor which is pressed and rolled.

Dualin, lithofracteur, Brain's powder, is a mixture of glycerine t
trate with sawdust, etc., which has previously been treated with n
acid or sulphuric acid. Explosive gelatine is guncotton impregn
with glycerine trinitrate. Artificial silk, which is very similar to nat
silk, is prepared by pressing collodion into water and treating the
fine fibres of collodion wool thus obtained with calcium sulphide, w
reduces them to silky cellulose fibres.

Lignin, xylogen, incrusting substance, occurs with cellulose as
chief constituent of wood, and is similar to it. It dissolves readil
HNO_3+KClO_3, which serves in separating it from cellulose. Bodies
taining lignin turn yellow in the air and light and also with aniline
phate, and beautifully red with a solution of phloroglucin in concentra
HCl (detection of lignin in paper).

Starches, Amylum. *Occurrence.*. They are found in nearly all pla
although not always, as microscopic granules of an organized struct
whose size and configuration differ in the various species of pla
and this fact is used to differentiate between the various starches.

The starch granule consists chiefly of starch, which is called sta
granulose and starch cellulose, also called farinose, which forms
structure of the grains and remains unchanged by the action of wa
etc.

Preparation. On a large scale it is chiefly prepared from potat
wheat, or rice, which are macerated with water to a paste and t
kneaded on sieves with water. The starch is hereby washed out
passes through the meshes of the sieve, while the cell membrane,
gluten, etc., remain behind. The starch is now allowed to se
and dried.

Properties. White odorless powder which is soluble in an aqu
solution of chloral hydrate but insoluble in cold water, alcohol,
ether. It attracts water from the air, and when treated with boi
water it is converted into a slimy mass which forms a paste on coo
and a hard mass on drying. If this paste is boiled for a long t
with considerable water, the starch dissolves and alcohol precipit

n this solution a white amorphous powder which is soluble in er (*soluble starch, amidulin*). The solution is dextrorotatory, on heating to 160–200° the starch is transformed into dextrin rch gum). On boiling with dilute acids starch is converted into trin and finally into dextrose, at the same time taking up water. the action of malt diastase it is first converted into soluble starch then into dextrin, and finally into maltose and isomaltose.

oncentrated sulphuric acid dissolves starch with the formation starch-sulphuric acid, which forms salts with bases. Concentrated tric acid dissolves starch, and on diluting with water xyloidin, $_2H_{19}O_9(NO_3)$, precipitates out; this xyloidin is explosive like the llulose nitrates. On heating with nitric acid oxalic acid is produced. he deep blue coloration obtained by an aqueous solution of iodine . 143) with starch is characteristic of dissolved starch, as well as the arch in the grains. This coloration disappears on heating and reappears on cooling, and is used in the detection of starch.

The most important forms of starch are wheat starch, potato starch, rrowroot starch, sago and tapioca or cassava starch.

Inulin, found in the roots of Inula helenium, is soluble in hot water nd turns yellow with iodine.

Glycogen, liver-starch, animal starch, occurs in the liver, in all developing animal cells, in many fungi, and in certain higher plants. It exists a greater extent in horse-muscles, in the fœtus, and in mollusks. On he death of the animal it is quickly transformed into dextrose. It is an morphous colorless powder which turns reddish brown with iodine and soluble in hot water, giving a dextrorotatory power to the solution.

Lichenin, moss starch, occurs in Iceland moss, is soluble in hot water, nd turns blue with iodine.

Dextrins, Starch Gum. *Occurrence and Formation.* Dextrins s the name given to a series of intermediary products produced n the transformation of the starches into sugar, and of these only *mylo-*, *erythro-*, *malto-*, and three *achroodextrins* have been closely tudied up to the present time. Dextrins are formed by gently roasting starch, as well as by the short action of malt diastase or saliva pon starch (occurrence in the crust of bread and in beer). It is prepared on a large cale (as a substitute for gum as an adhesive body) y moistening starch with 2 per cent. nitric acid and drying in the ir and then heating to 110°.

Properties. Yellow amorphous masses readily soluble in water nd dextrorotatory, but insoluble in alcohol. Most dextrins do ot reduce alkaline copper solutions even on boiling, and are only

II. ISOCARBOCYCLIC COMPOUNDS.

CONSTITUTION.

ocyclic compounds (p. 326) are those compounds whose ontains a ring-formed group of C atoms and are all derived ene, C_6H_6, whereby its H atoms are partly or entirely replaced alent atoms (p. 465) or by groups of atoms (side chains),

Cl	$C_6H_3(OH)_3$	$C_6H_2(CH_3)_4$	C_6Cl_6
benzene.	Pyrogallol.	Durene.	Hexochlorbenzene.

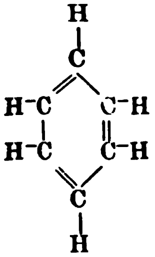
carbocyclic compounds therefore contain a group of six C ited together, 18 of the 24 valences having been satisfied, alences are free to unite with other atoms, etc. Although ompounds each of the 6 C atoms only has one free valence, behave somewhat like saturated compounds and cannot be into these without destruction of the molecule. For exam- turated hydrocarbon corresponding to benzene, C_6H_6, must ormula C_6H_{14} (p. 297), while benzene only slowly takes up H c., by addition and forms bodies up to C_6H_{12}, so that of the es of its 6 C atoms, 12 are always mutually satisfied in the but still in a different way from the isomeric unsaturated compounds, the olefines (p. 394).

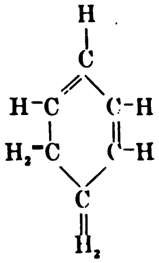
peculiar behavior of this carbon group of existing with e valences, as well as the chemical behavior of all the com- elonging thereto (see Substitution), and above all the isomeric ies of these compounds (see Isomerism, p. 466), can be best l by admitting that the 6 C atoms are alternately united to er by one or two bonds, and that the last C atom is united first, so that the 6 C atoms form a closed ring-like chain, a benzene ring (Kékulé's benzol theory), thus:

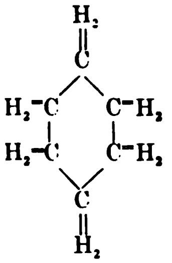
Besides the isocarbocyclic compounds with one C ring in the molecule we have those with several C rings chained and condensed together (p. 298).

Monovalent atoms, etc., may also, as mentioned on p. 461, unite directly with benzene and its derivatives, although not more than six are possible. The benzene ring remains closed in these compounds, and the double bonds of the C atoms are all of them or in part changed into single bonds:

Benzene, C_6H_6. Dihydrobenzene, C_6H_8. Hexahydrobenzene, C_6H_{12}.







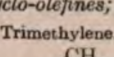
The benzene ring in C_6H_6 is also called tertiary, in C_6H_{12} secondary or reduced, in C_6H_8 and C_6H_{10} partially reduced.

These hydrogen addition products, also called *hydrocarbocyclic* compounds, such as hexahydrotoluene, $C_6H_{11}(CH_3)$, hexahydroxylene, $C_6H_{10}(CH_3)_2$, form with the naphthenes (see below) Caucasian petroleum. Most of them may be transformed into the corresponding isocyclic compound by oxidation. These addition products with their respective derivatives differ markedly from their mother-substances, as they behave like the aliphatic compounds and hence belong to the alicyclic compounds (p. 327); still in order to make the subject clear they will be treated in connection with their mother substances.

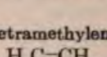
For example, di- and tetrahydrobenzene, C_6H_8 and C_6H_{10}, as well as their derivatives which still contain a few C atoms with double bonds, behave like the corresponding unsaturated aliphatic compounds. Hexahydrobenzene, C_6H_{12}, which contains the C atoms all with single bonds, behaves, with its derivatives, like a saturated aliphatic compound (see below). The most important compounds of this class are those of the terpene group, which will be considered later.

Closely related to the isocarbocyclic compounds and forming a connection with the aliphatic compounds we have those alicyclic compounds which form the simplest constituted compounds with C rings, namely, the *polymethylenes* or *naphthenes*, which consist of three or more methylene, groups, $^-CH_2^-$, or, as they are isomerides of the olefines, they are also called *cyclo-olefines;* e.g.,

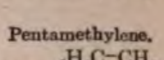
Trimethylene.



Tetramethylene.



Pentamethylene.



Hexamethylene, C_6H_{12}, is identical with the above-mentioned hexahydrobenzene, $C_6H_6(H)_6$ (p. 463).

They form the chief constituents of Caucasian petroleum (p. 341), and also occur in coal-tar and shale-oil, and in the resin-oil obtained in the distillation of colophonium. They behave like saturated aliphatic compounds, and differ from the isomeric olefines by their inability of forming addition products and their stability towards $KMnO_4$.

The acids of these hydrocarbons also occur in petroleum and are called *petrolic acids;* e.g., $C_6H_{10}(CH_3)(COOH)$. These acids are isomerides of the oleic acids, but cannot, like these, be converted into fatty acids.

SUBSTITUTION.

The most essential difference between the aliphatic and cyclic compounds is shown by substitution.

In the aliphatic hydrocarbons the hydrogen can only be directly replaced by other elements with difficulty. The halogens only have the power of expelling the hydrogen and of taking its place; hence these compounds are used in order to obtain new derivatives. In the cyclic hydrocarbons and their derivatives, on the contrary, the hydrogen of the benzene ring can not only be directly replaced by the halogens with ease, but also by the action of nitric acid or sulphuric acid, whereby the nitro group, $^-NO_2$, or sulphonic acid group, $^-SO_3H$, replaces the hydrogen, e.g.,

$$C_6H_6 + HO^-SO_2^-OH = C_6H_5^-SO_2OH + H_2O.$$

Benzene. Sulphuric acid. Benzenesulphonic acid.

$$C_6H_6 + 2\frac{HO}{HO}{>}SO_2 = C_6H_4{<}\begin{matrix}SO_2^-OH\\SO_2^-OH\end{matrix} + H_2O.$$

Benzenedisulphonic acid.

$$C_6H_6 + HO^-NO_2 = C_6H_5^-NO_2 + H_2O.$$

Nitric acid. Nitrobenzene.

$$C_6H_5OH + HO^-SO_2^-OH = C_6H_4(OH)(SO_3H) + H_2O.$$

Phenol. Sulphuric acid. Phenolsulphonic acid.

$$C_6H_5OH + HO^-NO_2 = C_6H_4(OH)^-(NO_2) + H_2O.$$

Phenol. Nitric acid. Nitrophenol.

These sulphonic acid and nitro compounds are isomeric with the sulphurous acid and nitrous acid compounds. Still in the sulphonic and nitro bodies the sulphur or the nitrogen is directly united carbon atom, while in the sulphites and nitrites the binding place through the oxygen atoms: $C_2H_5-O-SO-OH$, ethyl ite; C_2H_5-ONO, ethyl nitrite (differentiation by nascent hydro- ee p. 319).

at portion of the benzene molecule remaining after substitution ed the benzene nucleus.

ith the aliphatic bodies the sulphuric acid and nitric acid act only the alcohols or unsaturated hydrocarbons and form esters with them 357 and 395); e.g.,

$$\underset{\text{Ethyl alcohol.}}{C_2H_5OH} + HO-SO_2-OH = \underset{\text{Ethylsulphuric acid.}}{C_2H_5-O-SO_2-OH} + H_2O.$$

e sulphonic acid and nitro compounds of the aliphatic compounds nly be obtained in an indirect manner; thus, by the action of the iodides upon silver sulphite or nitrite:

$$AgNO_2 + C_2H_5I = C_2H_5-NO_2 + AgI;$$
$$Ag_2SO_3 + 2C_2H_5I = \underset{\text{Ethyl sulphonic acid ethyl ester.}}{C_2H_5-SO_2-O-C_2H_5} + 2AgI.$$

ating the last ester with water, alcohol is split off and an aliphatic onic acid is obtained.

he union of the halogen atoms in the benzene ring is much r than in the open C chain of the aliphatic compounds, so that they ally cannot be replaced by other groups by double decomposition. polyvalent element never replaces several hydrogen atoms in enzene molecule, therefore compounds like $C_6H_4=O$ or $C_6H_3\equiv N$ nknown. On the contrary, a polyvalent radical can replace al H atoms in a benzene molecule (see Terpenes and Alkaloids). e amido bodies are obtained from the nitro bodies by reduction nascent hydrogen):

$$C_6H_5NO_2 + 6H = C_6H_5NH_2 + 2H_2O.$$

In this reduction *azo* compounds (*azote* = nitrogen) appear as mediate products. They contain the divalent group $-N=N-$, isting of two trivalent N atoms, which is united by both valences two cyclic radicals.

losely related to these we have the *diazo* compounds which con- the group $=N\equiv N$, consisting of one pentavalent and one tri- nt N atom, which is united with only one valence with one C n of one cyclic radical; e.g.,

$$\underset{\text{Azobenzene.}}{C_6H_5-N=N-C_6H_5} \qquad \underset{\text{Diazobenzene nitrate.}}{(NO_3)(C_6H_5)=N\equiv N}$$

ochlortoluene, $C_6H_4Cl-CH_3$; Benzyl chloride, $C_6H_5-CH_2Cl$;
ol, $C_6H_4(OH)-CH_3$; Benzyl alcohol, $C_6H_5-CH_2-(OH)$.

f the hydrogen atoms of the aliphatic side chain are replaced by roxyl, we obtain true alcohols of the benzene series, which on ation yield aldehydes, ketones, and acids:

H_5-CH_3,	$C_6H_5-CH_2OH$,	C_6H_5-CHO,	C_6H_5-COOH.
yl benzene.	Benzyl alcohol.	Benzald.hyde.	Benzoic acid.

ubstitution in the nucleus is indicated as *endo*-substitution, and in ide chain as *exo-;* thus, endochlortoluene, $C_6H_4Cl-CH_3$, and exochlor-ne, $C_6H_5-CH_2Cl$; ω- denotes substitution at the last C atom of the chain ($C_6H_5-CH_2-CH_2Cl$, ω-chlorethyl benzene), while α-, β-, etc., te substitution at the succeeding C atoms; thus, $C_6H_5-CH_2-CHCl-CH_3$ chlorpropyl benzene).

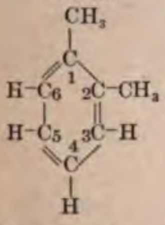
rom this it follows that, by substitution in the benzene ring or e side-chain, we may have a great variety of benzene derivatives, the number becomes still greater on account of the isomerism ible on account of the structure of benzene.

f any hydrogen atom in the benzene molecule is replaced by an-r atom or an atomic group, each compound thus obtained can exist in one modification. Hence we have only one chlorbenzene, nitrobenzene, one methyl benzene, etc. The 6 H atoms of benzene e the same value, depending upon their mutual position.

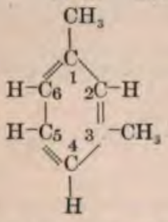
If, on the contrary, two hydrogen atoms of the benzene are replaced two similar or different monovalent atoms or atomic groups, it follows that three modifications of such a compound are possible, in fact all three theoretically possible isomers of most com-nds are known and are designated as follows:

Ortho and Meta and Para compounds.

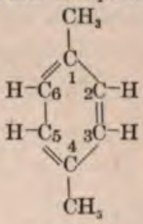
a)



(*b*)



(*c*)

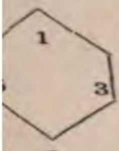


If, for example, we admit that two CH_3 groups are substituted for H atoms, then these methyls take the following positions if we mber the C atoms from 1 to 6 as above: (*a*) 1:2, (*b*) 1:3, (*c*) 1:4.

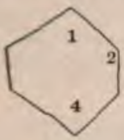
two processes it follows that the splitting off of H_2O takes place where only one H atom of the NH_2 group)H group, which is designated as *lactame formation*, or he NH_2 group are taken away, which is called *lactime*

ır hydrogen atoms of benzene are replaced by equivadicals, then necessarily three isomers are possible, x hydrogen atoms of benzene are substituted, only one possible; thus we have only one pentachlorbenzene, hexachlorbenzene, C_6Cl_6, etc.

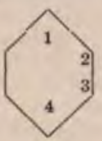
of the tri- and tetra-substitution products are designated eighboring), *s* (*symmetrical*), *a* (*asymmetrical*). The folow the relative positions of substitution:



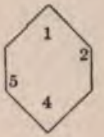
s



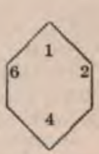
a



v



s

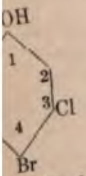


a

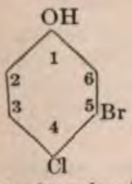
, etc., substituted atoms or radicals are different, then the ners are still greater; thus, six isomers of the formula) and ten isomers of the formula $C_6H_3(X)(Y)(Z)$ are pos-

the corresponding bi-derivatives (p. 467), the C atoms of the cleus are numbered from 1 to 6, and the group containing having the smallest atomic weight united directly with the ccupies the position 1. The remaining substituted groups are dicated in their order, so that the increased atomic weight of directly united with the nucleus is shown. If two equal atoms d with the nucleus, then the other atoms of the group are conccording to their atomic weights.

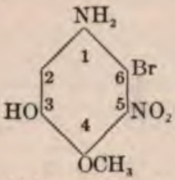
several side-chains containing carbon the one which causes the crease in molecular weight takes first place; for example,



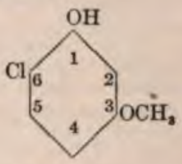
bromphenol
1·3·4.



Chlorbromphenol
1·4·5.



Amino-oxymethoxy-
nitrobrombenzene 1·3·4·5 6.

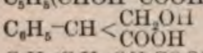


Oxymethoxychlor-
benzene 1·3·6.

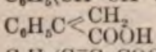
e. Bibasic Phenol Acids.

Oxyphthalic acids,	$C_6H_3(OH)(COOH)_2$	or	$C_8H_6O_5$.
Dioxyphthalic acids,	$C_6H_2(OH)_2(COOH)_2$	or	$C_8H_6O_6$.

f. Alcohol and Ketone Acids.

Mandelic acids,	$C_5H_5(CHOH-COOH)$	or	$C_8H_8O_3$.
Tropic acid,	 $C_6H_5-CH<\genfrac{}{}{0pt}{}{CH_2OH}{COOH}$	or	$C_9H_{10}O_3$.
Phenyllactic acid,	$C_6H_5(C_2H_5 \cdot OH \cdot COOH)$	or	$C_9H_{10}O_3$.
Benzoylacetic acid,	$C_6H_5-CO(CH_2-COOH)$	or	$C_9H_8O_3$.

g. Unsaturated Acids.

Cinnamic acid,	$C_6H_5(CH=CH-COOH)$	or	$C_9H_8O_2$.
Atropic acid,	 $C_6H_5C\lessgtr\genfrac{}{}{0pt}{}{CH_2}{COOH}$	or	$C_9H_8O_2$.
Phenylpropiolic acid,	$C_6H_5(C\equiv C-COOH)$	or	$C_9H_6O_2$.
Oxycinnamic acid,	$C_6H_4(OH)(CH=CH-COOH)$	or	$C_9H_8O_3$.
Dioxycinnamic acid, (caffeic and umbellic acids,)	$C_6H_3(OH)_2(CH=CH-COOH)$	or	$C_9H_8O_4$.
Trioxycinnamic acid,	$C_6H_2(OH)_3(CH=CH-COOH)$	or	$C_9H_8O_5$.

roperties. They nearly all form crystals which are soluble with
ulty in water, and hence are precipitated from the solution of their
by mineral acids. Those with simple constitution can be sublimed
distilled, while the others generally split off CO_2 on heating. This
age takes place with all of them on heating with alkali hy-
ides. In other respects they correspond to the aliphatic acids, but as
are, on the other hand, benzene derivatives, therefore they may be
e to undergo the transformations which are common to benzene. By
introduction of HO groups into the benzene nucleus of these acids
produce phenol acids, also called oxyacids, and when HO groups are
oduced in the side-chain we obtain alcohol acids which correspond in
t properties with the phenol acids.

Preparation. 1. By the oxidation of the corresponding aldehyde and
nary alcohol.

2. By the oxidation of the homologues of benzene (p. 473). If the
ologues also contain the $-OH-$, NO_2-, NH_2 groups, etc., acids with
e groups are obtained.

3. On the saponification of the corresponding nitrile; e.g., $C_6H_5CN +$
$O=C_6H_5-COOH+NH_3$.

. By the action of carbon dioxide derivatives of benzene upon certain
zene derivatives (see Benzoic Acid and Salicylic Acid).

. The unsaturated acids are obtained according to Perkin's reaction
he action of cyclic aldehydes upon fatty acids (see Cinnamic Acid),
from the monohalogen derivatives of the saturated acids by means
lcoholic caustic alkali (p. 323).

ccurrence. They occur in many resins and balsams and as NH_2
vatives in the animal organism.

more aliphatic character. By substitution in the benzene in the side-chain we obtain compounds of a mixed character. tives of toluene containing the radical $C_6H_5-CH_2-$ are call the radical C_6H_5-CO, *benzoyl*, the radical $-C_6H_4-CH_3$, *tolyl* compounds. In regard to the further nomenclatu toluene derivatives see p. 471.

Chlortoluenes, $C_6H_4Cl(CH_3)$; all three isomers are known as brom- and iodotoluenes (Preparation, p. 474).

Nitrotoluenes, $C_6H_4(NO_2)CH_3$; all three isomers are know action of concentrated nitric acid upon toluene we obtain the para- and the liquid orthonitrotoluene.

Toluidines, amidotoluenes, $C_6H_4(NH_2)(CH_3)$; the three i formed in the reduction of the three nitrotoluenes. Ortho- toluidine are fluids and paratoluidine a solid.

Benzyl chloride, $C_6H_5-CH_2Cl$, as well as the bromide and colorless liquids with a pungent odor (Preparation, p. 474).

Benzal chloride, $C_6H_5-CHCl_2$, and **benzotrichloride,** C_6H formed on the further action of chlorine upon boiling toluene.

Benzylamine, $C_6H_5-CH_2NH_2$, is produced by heating benz with ammonia and consists of a colorless liquid with a stro reaction.

Benzylcyanide, $C_6H_5-CH_2CN$, forms the ethereal oil of the and garden cresses (Lepidium sativum) accompanied by

Benzylisosulphocyanide, benzyl mustard-oil, $C_6H_5-CH_2-N$

Benzylalcohol, $C_6H_5-CH_2OH$, occurs as the cinnamic a acid benzyl ester in storax, balsam of Peru, and Tolu and i from benzaldehyde by the action of alkali hydroxides hydrogen or by heating benzylacetate with caustic alkalies It is a colorless thick liquid, boiling at 207°:

$$\underset{\text{Benzylchlorid.}}{C_6H_5-CH_2Cl}+\underset{\text{Pot. acetate.}}{C_2H_3O_2K}=\underset{\text{Benzylacetate.}}{C_6H_5-CH_2(C_2H_3O_2)}+KCl$$

$$\underset{\text{Benzylacetate.}}{C_6H_5-CH_2(C_2H_3O_2)}+KOH=\underset{\text{Benzyl alcohol.}}{C_6H_5-CH_2OH}+C_2H_3O_2$$

Benzylaldehyde, oil of bitter almond, C_6H_5-CHO, is an the aliphatic aldehydes and is obtained by distilling a salt acid with a salt of formic acid (p. 351, 12), also by heati chloride with water: $C_6H_5-CHCl_2+HOH=C_6H_5-CHO+2$

Ordinarily it is prepared from bitter almonds by t position of the glycoside amygdalin contained therein Thus obtained it is generally mixed with hydrocyani $C_6H_5-CHO(CN)$ (see p. 351, 9) and forms the oil of bitte of the druggist. Benzaldehyde is a colorless liquid, boilin having a characteristic odor, and giving all the reactio

s large, shining crystals which have a
ich are readily sublimable. These crystals
le with difficulty in cold water, but more rea
easily soluble in alcohol and ether.

oic acid or *benzoates* are mostly readily soluble
le precipitates neutral benzoate solutions formin
enzoate, $(C_6H_5-COO)_3Fe$, which is soluble in fatt

cid, $C_6H_4(NH_2)(COOH)$. Its ethyl ester is called
l as a local anæsthetic.
O–NH$_2$, corresponds to acetamide and by splitting
nto
-CN, a liquid having an odor similar to oil of bitter
itriles behave like the aliphatic nitriles (p. 330).
acid, $C_6H_4(NH_2)(COOH)$, *anthranilic acid*, is pro-
of indigo and is prepared from phthalimide (p. 497),
hesis of indigo. Its methyl ester is a constituent of
nge flowers, pomegranate, and jasmin flowers, and
tion of perfumes.

zoic acid, $C_6H_4<\begin{matrix}COOH\\SO_2-NH_2\end{matrix}$, when heated yields
zoic acid anhydride, orthobenzoic acid sulphimide,
$<\begin{matrix}CO\\SO_2\end{matrix}>NH$, forms white crystals which are diffi-
er but readily soluble in alcohol and ether, and
sweeter than cane-sugar, and hence used as a
g *m-* and *p*-compounds do not taste sweet. The
the "readily soluble saccharin" and contains water
is called *crystallose*, *saccharose*.
$C_6H_5-COO(C_6H_5\cdot CH_2)$, is used in medicine under the
d its solution in oil is called peruol.
$C_6H_5\cdot CO\cdot O\cdot O\cdot OC\cdot C_6H_5$, and
$H_5\cdot CO\cdot OOH$, are to be considered as H_2O_2, in which
een replaced by benzoyl. The first melts at 110° and

e, C_6H_5-COCl, is obtained from PCl_5 and benzoic acid
less liquid which is used in introducing the benzoyl
mpounds:

$$H+C_6H_5-COCl=C_6H_5-OOC-C_6H_5+HCl;$$
$$H_2+C_6H_5COCl=C_6H_5-NH-CO-C_6H_5+HCl.$$

adily in the presence of caustic alkalies (Schotten-Bau-
d serves in detecting $-NH_2$, $-OH$, and $=NH$ in aromatic
ounds.
, $C_{19}H_{20}N_2O_4$, is benzoylornithin, $(C_4H_7)(NH\cdot C_6H_5\cdot CO)_2-$
bird urine, especially on feeding with benzoic

cid, $C_6H_4(O{\cdot}OC{\cdot}CH_3){-}COOH$, *aspirin*, forms crystals
ater.

cid, $HOOC(HO)H_3C_6{-}S{-}S{-}C_6H_3(OH){-}COOH$. The
hioform, is used in medicine.

enzoate, $C_6H_3(NH_2)(OH)(COOCH_3)$. The *p*-amido-
called *orthoform*, the *m*-amido-*p*-oxy-compound, *new*
do-*o*-oxy-compound combined with dimethylglycocoll,
ed in medicine.

-methyloxybenzyl alcohol, $C_6H_4(O{\cdot}CH_3)(CH_2OH)$, is
ldehyde by reduction (by caustic alkali, see Benzal-
crystals melting at 45°.
$C_6H_4(O{\cdot}CH_3)(CHO)$, is prepared by the oxidation of
and is the odoriferous principle of the hawthorn and
boils at 248°.
$(O{\cdot}CH_3)(COOH)$, produced by the oxidation of anisic
forms crystals which melt at 185°.

henols, $C_6H_3(OH)_2(CH_3)$, *and their Derivatives.*

ossible dioxytoluenes are known, but only orcin and
will be treated of. The alcohol phenols or dioxybenzyl
(CH_2OH), related to these are not known free, never-
dioxybenzyl aldehydes and dioxybenzoic acids have
hetically.

$)_2(CH_3)$, exists free to a slight extent in the lichens of
Evernia, and Lecanora, and can be obtained from the
96), contained in these lichens. Orcin forms colorless
e watery solution turns bluish violet with ferric chlo-
deep violet with a solution of chloride of lime.
l orcin solution is allowed to stand in the air it absorbs
n and a red crystalline pigment, *orcein*, $C_{28}H_{24}N_2O_7$,
of the *orseille pigments* (called when pure persio, cud-
produced. These also may be obtained directly by
ve-mentioned lichens with ammonia.
l orcin solution is allowed to stand with alkali car-
nt, which becomes red with acids and blue again with
This consists chiefly of *azolitmin*, $C_7H_7NO_4$.

in, $C_6H_3(OH)_2(CH_3)$, obtained from creosol by heating
roscopic crystals.

$H_3)(OCH_3)(OH)$, methyl homopyrocatechin, is a liquid
ch is very similar to guaiacol (p. 480), and forms, when
is obtained from beech-wood tar by fractional dis-
00° and 220°. It forms a yellowish liquid having a
odor. Its alcoholic solution turns deep blue with a
ferric chloride solution and dark green with a larger
al is the name given to a mixture of guaiacol and

alcohol, $C_6H_3(OH)_2(CH_2OH)$, is unknown.
aldehyde, $C_6H_3(OH)_2{-}CHO$, obtained from vanillin
pyrocatechin by means of the chloroform reaction
ns colorless crystals which are soluble in water, and
lution turns deep green with ferric chloride.

2. Ethyl Benzene Compounds.

ne, $C_6H_5(C_2H_5)$ or $C_6H_5-CH_2-CH_3$, is a colorless liquid boil-
d is only obtained synthetically.
yl alcohol, $C_6H_5(C_2H_4 \cdot OH)$, forms the chief constituent of
s principle of the rose and hence also of the ethereal oil of

henylketone, $C_6H_5-CO-CH_3$, acetophenone, a colorless liquid
culiar odor.
atic ketones may be obtained by warming an aromatic hydro-
h an acid chloride in the presence of $AlCl_3$ (Friedel-Craft's
thesis):

$$C_6H_6+CH_3-COCl=C_6H_5-CO-CH_3+HCl.$$

enzoate is distilled with another organic salt, then mixed ketones
ined:

$$C_6H_5-COONa+CH_3-COONa=Na_2CO_3+C_6H_5-CO-CH_3$$

henyl benzene, styrene, cinnamol, $C_6H_5-CH=CH_2$, is produced by the
ation of cinnamic acid with lime, when CO_2 is evolved. It occurs in
torax balsam and is a colorless liquid which boils at 146° and which
rgoes polymerization readily.

Phenylacetic acid, alphatoluic acid, $C_6H_5-CH_2-COOH$, the only
neric toluic acids of ethyl benzene known, occurs in the urine and in
putrefactive products of proteids.

Oxyphenylacetic acid, $C_6H_4(OH)-CH_2-COOH$, occurs in urine and is
roduced in the putrefaction of tyrosin.

Dioxyphenylacetic acid, $C_6H_3(OH)_2-CH_2-COOH$, homogentisic acid
(p. 494), occurs sometimes in the urine, which causes it to turn dark on
standing.

Oxyphenylamido acetic acid, $C_6H_4(OH)-CH(NH_2)-COOH$, *glycin*, is
used as a developer in photography.

Mandelic acid, phenylglycollic acid, $C_6H_5-CHOH-COOH$, is obtained
from benzaldehyde and $HCN+HCl$ (p. 405) or from amygdalin (see
below). The lævo and the inactive modifications are known.

Mandelic acid nitrile diglucose, $C_6H_5-CHO(C_{12}H_{21}O_{10})-CN$, amygdalin,
the glucoside of the bitter almond, etc. (p. 384), forms colorless crystals
which on warming with dilute acids or on standing with water by the
action of the ferment emulsin contained in the plants, decomposes
into glucose, hydrocyanic acid, and benzyaldehyde (oil of bitter alm-
onds): $C_{20}H_{27}NO_{11}+2H_2O+2C_6H_{12}O_6+HCN+C_6H_5-CHO$. With zymase
it decomposes into glucose and mandelic acid nitrile glucose, C_6H_5-
$CHO(C_6H_{11}O_5)-CN$, which is only further split by emulsin like amygdalin.
If amygdalin is boiled with bases a development of NH_3 takes place and
amygdalic acid, $C_{20}H_{28}O_{13}$, is produced, which on heating with acids
ses into glucose and mandelic acid (see above).

POUNDS WITH NINE CARBON A

1. Trimethyl Benzen

e three trimethyl benzenes, $C_6H_3($
umene (position 1, 2, 4), and
n coal-tar.
esitylene, $C_6H_3(CH_3)_3$, is obtai
c acid; hence it has the st
aving a peculiar odor, bo
three acids on successive
esitylenic acid, $C_6H_3(CH_3)_2CO$
vitic acid, $C_6H_3(CH_3)(COOH)$
imesic acid, $C_6H_3(COOH)_3$,
eudocumene, $C_6H_3(CH_3)_3$,
the following two isome
ylic acids, $C_6H_3(CH_3)_2CO$
ethylphthalic acid, $C_6H_3($
ilic acid, $C_6H_3(CH_3)($
emellitic acid, $C_6H_3(CO$
emellithene, $C_6H_3(CH$
idation
emellitic acid, $C_6H_3($
emillitic acid, C_6H_3
trimesic and tri

2

he radical C
yl (p. 437).

H NINE CARBON ATOMS UNITED TOGETHER.

Trimethyl Benzene Compounds.

hyl benzenes, $C_6H_3(CH_3)_3$, mesitylene (position 1, 3, 5),
ition 1, 2, 4), and hemellithene (position 1, 2, 3),

$_3(CH_3)_3$, is obtained when acetone is heated with
nce it has the structure (1, 3, 5) (p. 470). It is a
eculiar odor, boiling at 163°, and which yields the
ds on successive oxidation:
l, $C_6H_3(CH_3)_2COOH$, isomer of the xylic acids.
$H_3(CH_3)(COOH)_2$, isomer of methylphthalic acid.
$C_6H_3(COOH)_3$, isomer of trimellitic acid.
$C_6H_3(CH_3)_3$, a liquid boiling at 169° and which first
g two isomeric acids:
$H_3(CH_3)_2COOH$, and then on further oxidation
acid, $C_6H_3(CH_3)(COOH)_2$, and its isomer,
$C_6H_3(CH_3)(COOH)_2$, which is readily oxidized to
l, $C_6H_3(COOH)_3$.
$C_6H_3(CH_3)_3$, a liquid boiling at 175° and which yields
d, $C_6H_3(CH_3)_2COOH$, and finally
l, $C_6H_3(COOH)_3$, an isomer of the benzene tricarboxy
nd trimellitic acids.

2. Allyl Benzene Compounds.

C_3H_5 may act trivalent as glyceryl and monovalent
. As the derivatives of the allyls of the fatty series
turated compounds and pass readily over into the
l compounds, so also the aromatic derivatives of the
rted into the saturated propylbenzene derivatives by
ascent hydrogen.

, $C_6H_5-C_3H_5$ or $C_6H_5-CH=CH-CH_3$, is obtained by the
lyl upon brombenzene in the presence of sodium (p. 472).
melling liquid.
camphor, $C_6H_4(O \cdot CH_3)(C_3H_5)$, the chief constituent of oil
estragon, crystallizes on cooling these oils as colorless
t at 21°, and boil at 223°.
$_3(OH)(O \cdot CH_3)(C_3H_5)$, contained in the ethereal oil of
ta (besides $C_{10}H_{16}$ see terpenes); forms an aromatic-
ich boils at 252°, and which forms the isomer isoeugenol
stic potash.
cohol, $C_6H_3(OH)(O \cdot CH_3)(C_3 \cdot H_4 \cdot OH)$, occurring in the
, melts at 85°, and yields vanillin on oxidation (p 494).
$OCH_3)_3C_3H_5$, contained in the ethereal oil of Asarum

m, Matiko, and Calamus.

ol, $C_6H(O{\cdot}CH_3)_2(O{\cdot}CH_2{\cdot}O)(C_3H_5)$, contained in the ethereal oil
parsley, forms shining crystals which melt at 32°.

frol, $C_6H_3(O{\cdot}CH_2{\cdot}O)(C_3H_5)$, allylpyrocatechin methylene ether, is the
constituent of the ethereal oil of sassafras and of the camphor-oil
ned in the preparation of camphor.

ubebin, $C_6H_3(O{\cdot}CH_2{\cdot}O)(C_3H_4{\cdot}OH)$, occurs in cubebs.

Cinnamyl alcohol, cinnamic alcohol, phenylallylalcohol,
$H_5{-}C_3H_4(OH)$ or $C_6H_5{-}CH{=}CH{-}CH_2OH$, occurs as cinnamic acid
er in storax and is separated therefrom by distillation with caustic
kali. It forms needle-shaped crystals which melt at 33°, have an
dor similar to the hyacinth, and are not very soluble in water. On
xidation it yields cinnamic aldehyde and cinnamic acid.

Cinnamic aldehyde, $C_6H_5{-}CH{=}CH{-}CHO$, the chief constituent of the oil of cinnamon and cassia, forms a colorless liquid boiling at 246°, is insoluble in water, and has an odor similar to cinnamon. It is oxidized to cinnamic acid even in the air.

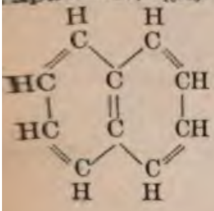
Cinnamic acid, β-phenylacrylic acid, $C_6H_5{-}C_3H_3O_2$ or $C_6H_5{-}CH{=}CH{-}COOH$, occurs in certain gum benzoins, in storax, Peru and Tolu balsam. It is prepared by boiling storax with caustic alkali and precipitating the alkali cinnamate by HCl or by boiling benzaldehyde with dry sodium acetate and acetic anhydride, which abstracts water (Perkin's reaction, which may be made to undergo numerous modifications): $C_6H_5{-}CHO+CH_3{-}COONa = C_6H_5{-}CH{=}CH{-}COONa+H_2O$; or from benzal chloride and sodium acetate:

$$C_6H_5{-}CHCl_2+CH_3{-}COONa = C_6H_5{-}CH{=}CH{-}COOH+NaCl+HCl.$$

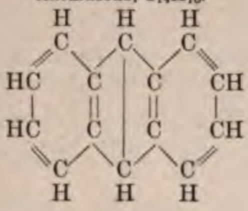
Cinnamic acid forms colorless and odorless crystals which melt at
133° and which are difficultly soluble in cold water. Ferric chlorid
precipitates yellow ferric cinnamate from its solution. On oxidat
it yields benzaldehyde and benzoic acid (p. 473).

Sodium cinnamate, $C_6H_5{-}CH{=}CH{-}COONa$, is used in med
as *hetol*. Besides the ordinary cinnamic acid three modificat
the same structure are known which are readily converti
ordinary cinnamic acid, while this latter cannot be transfo
the other modifications. These are called *allocinnamic* a
isocinnamic acid, which is obtained synthetically, and
cinnamic acid, which is found with ordinary and all
in the cleavage acids of the alkaloids associated wit

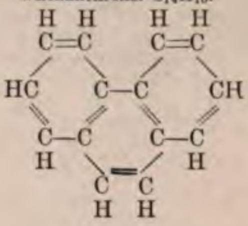
aphthalene, $C_{10}H_8$.



Anthracene, $C_{14}H_{10}$.

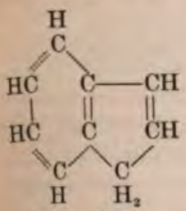


Phenanthrene. $C_{14}H_{10}$.

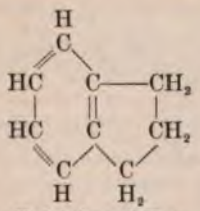


Fluoranthrene, $C_{15}H_{10}$, pyrene, $C_{16}H_{10}$, chrysene, $C_{18}H_{12}$, naphthacene, $C_{18}H_{12}$, picene, $C_{22}H_{14}$, all have a similar structure and are found in that part of coal-tar boiling above 360°. They are all colorless crystals and their derivatives yield even a larger number of isomers than the benzenes.

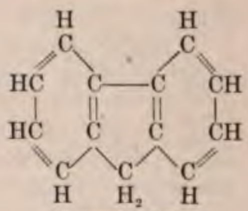
Condensed compounds of benzene rings with rings poorer in C (p. 463) which have two mutual C atoms are also known, namely:



Indene, C_9H_8.



Hydrindene, C_9H_{10}.

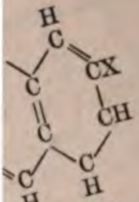


Fluorene, $C_{13}H_{10}$.

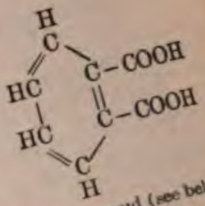
Besides these we also have condensed compounds of the isocarbocyclic with the heterocyclic compounds (see the latter). Condensed compounds which consist of two ring systems which have 3 or 4 mutual atoms are also known (see Terpenes and Alkaloids).

1. Naphthalene Compounds.

These compounds contain two benzene rings with two common C atoms. Naphthalene may yield two series of monosubstitution derivatives (α and β) according as the substituting body is introduced next to one of the two hydrogen-free C atoms or removed therefrom, thus:



β-Compounds.



o Phthalic acid (see below).

ydrogen atoms are substituted by the same possible, as follows, making use of the figures 4; 1:5; 1:6; 1:7; 1:8; 2:3; 2:6; 2:7. The 5 and 1:6; 2:8 and 1:7 are identical. On the odies the number of isomers is still greater.

s. *Preparation.* On the dry distillation of ds, especially if their vapors are passed through t is a chief constituent of coal-tar). On cooling tar boiling between 210° and 240° impure naphhich is purified by sublimation.

red synthetically in many ways; thus (analogous to sing the vapors of phenylbutylene over red-hot lead $=C_{10}H_8+4H$.

hining colorless plates which melt at 80° and boil ch slowly volatilize at 15° as well as with steam. It odor and a burning taste, and is insoluble in water lcohol, ether, chloroform, and fatty oils. It is oxidized c acid into orthophthalic acid (p. 497), from which it this acid takes the ortho position (see above). This ence naphthalene indirectly, is the starting-point in the manufacture of artificial indigo (p. 548).

ncentrated nitric acid we obtain mono-, di-, or trinitro ne, depending upon the extent of action. These nitro s are readily converted by reduction into the correspondo naphthalenes (naphthylamines). By concentrated sulcid we obtain the naphthalene sulphonic acids, $C_{10}H_7-SO_3$ n fusion with alkali hydroxides yield the naphthols, $C_{10}H_7(O$ c first produces addition products rupturing the double b C atoms, and then it forms substitution products.

thols, $C_{10}H_7(OH)$. On heating naphthalene with sulphu isomeric naphthalene sulphonic acids, $C_{10}H_7(SO_3H$

---

ed with alkali hydroxides yield forms colorless plates which soluble in alcohol. It melts at chloride and give a violet fl with chlorine-water. α-Nap

ethylether, nerolin, C and is used as a perfu benzoate, benzonaph disinfectant.

monosulphonic is used as a photogr β-naphtholdisulpho preservativ $C_{10}H_5(NO$ yellow. $C_{10}H_4O$ when i both of wh quinone dyestu C_{10} at 95°

by fusing anthraquinone sulphonic acid with caustic alkalies:

$$H_7O_2(SO_3H)+2KOH=KHSO_3+HOH+C_{14}H_7(OK)O_2;$$
$$C_{14}H_7(OK)O_2+KOH=H_2+C_{14}H_6(OK)_2O_2;$$

compoun [illegible] composed by HCl into alizarin.

ties. Technical alizarin is a yellowish-brown paste, and it forms red needles which are not readily soluble in water y soluble in alcohol and ether, producing a yellow solution. like a substituted diphenol, as an acid (p. 474), and dissolves with a purple-red color. Aluminium and stannic salts form cipitate, ferric salts a dark-violet with solutions of alizarin akes). In calico-printing the figures are printed on the ith the above-mentioned salts and the goods are then water in which alizarin is suspended, when the colored com-alizarin with the metal deposits at the place mordanted. is mordanted with alum and oil then alizarin produces ful turkey-red color.

of the aloes, which differs according to the variety of aloes, d barbaloin, $C_{16}H_{16}O_7+3H_2O$, capaloin, $C_{16}H_{16}O_7$, nataloin, all of which are derivatives of anthraquinone.

dioxyanthraquinones, $C_{14}H_5(CH_3)(OH)_2O_2$ or $C_{15}H_{10}O_4$. One the chrysophanic acid which is found in the senna leaves, in f the rhubarb, and in certain lichens. It forms golden-yellow ich are soluble in alkalies with a purple-red color. Chrysarobin, the active constituent of the drug called Goa or Arroroba It is a yellowish crystalline powder, which is not readily soluble nd ammonia, but forms a yellow solution with caustic alkalies. g the alkaline solution with air it turns red and contains then nic acid: $C_{30}H_{26}O_7+4O=2C_{15}H_{10}O_4+3H_2O$.

anthraquinones, $C_{14}H_5(OH)_3O_2$. One of these, called purpurin, h alizarin in the roots of the madder and may be formed from oxidation. It dyes wool in a similar manner to alizarin.

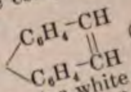
trioxyanthraquinones, $C_{14}H_4(OH)_3(CH_3)O_2$. One of these, ccurs in the rhubarb roots, aloes, bark of the black alder, and eaves. It forms orange-yellow needles.

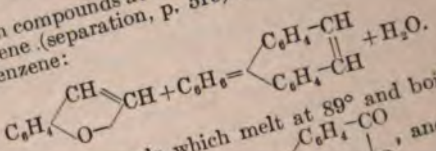
tetraoxyanthraquinones, $C_{14}H_3(CH_3)(OH)_4O_2$. One of these, rs sometimes with emodin.

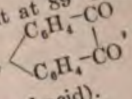
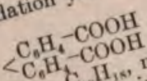
cene dyes. Many artificial dyes are derived from alizarin by g $-OH$ and NH_2 groups, producing alizarin carmin, alizarin izarin blue, alizarin bordeaux, alizarin cyanin, alizarin green, rin, anthrapurpurin, anthracene blue, anthracene brown.

3. Phenanthrene Compounds.

ke the anthracene compounds, contain three benzene nuclei ommon C atoms.

threne, $C_{14}H_{10}$ or  $<\begin{matrix} C_6H_4-CH \\ \| \\ C_6H_4-CH \end{matrix}$ (structure, p. 513), is obtained y carbon compounds at a white heat, and hence occurs in coal- anthracene (separation, p. 515) and also by heating benzofurane with benzene:



t forms colorless crystals which melt at 89° and boil at 340°, and oxidation yields phenanthraquinone,  $<\begin{matrix} C_6H_4-CO \\ | \\ C_6H_4-CO \end{matrix}$, and then diphenic id,  $<\begin{matrix} C_6H_4-COOH \\ C_6H_4-COOH \end{matrix}$ (*o*-biphenyldicarboxyl acid).

Retene, $C_{18}H_{18}$, methylisopropylphenanthrene, occurs in the tar from oniferæ and certain earth resins, and

Perhydroretene, $C_{18}H_{32}$, fichtelite, contained in the turf from fossil pines; both form colorless crystals.

4. Indene and Fluorene Compounds.

These contain benzene and pentamethylene rings (p. 464) with common C atoms (structure, p. 513).

Indene, C_9H_8, occurs in coal-tar and is a liquid, boiling at 180° and having an odor similar to naphthalene and yielding *o*-phthalic acid (p. 514) on oxidation. Its name is derived from the fact that on substituting an $=CH_2$ group of indene by $=NH$ we obtain indol (p. 547).

Hydrindene, C_9H_{10}, accompanies pseudocumene (p. 499) and is produced by the action of nascent hydrogen upon indene. It boils at 177°.

Fluorene, $C_{13}H_{10}$, has already been discussed on p. 505.

Carminicacid, $C_{24}H_{22}O_{14}$, carmine red, contains probably two hydrindene derivatives in the molecule. It occurs in the flowers of the Monarda didyma, in cochineal, in the kermes berries, and forms red masses, which are soluble in water and alcohol, with a yellowish-red color and which turn crimson red in the presence of alkalies. The carmine of commerce is a clay lake (p. 250) of carminic acid.

Compounds of the Terpene Group.

This group includes the terpenes and the varieties of camphors. Terpenes are the isomeric hydrocarbons having the formula $C_{10}H_{16}$ or their polymers which are either dihydrocymenes (p. 519) or are camphenes. The latter have a **benzene ring in which two C atom** are united bridge-like with another **C atom.**

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terpenes contain only
atoms in the benzene rin
s or groups of atoms can
s of the benzene ring will
The terpenes are also hy
pounds (p. 327), the cam
or alcohol group,
benzene ring with sin
alcohol groups are n
thetically.

The terpenes and
are called ter
or terpane, C
the camphene
dihydrocamp
We also kno
camphors.
which ar
cyclic t
As the

be transformed into each
ment of the atoms, be converted
split off from compounds of the second series depen
by the chemical action the C atoms on the dotted lines are separat
ducing an isopropyl group in the *p*-position to the methyl group.

The terpenes boil at 160°–190° and their boiling-points are s
together that they cannot be separated by fractional distil
while this can be done on the contrary by their ability of f
well-defined crystalline compounds with HCl, HBr, Br_2, or
These compounds may be differentiated by their different m
points. They are distinguished as *terpenes*, $C_{10}H_{16}$, *sesquite*
$C_{15}H_{24}$, *diterpenes*, $C_{20}H_{32}$, and *polyterpenes*, $(C_{10}H_{16})x$, and form
the exception of the camphenes and the polyterpenes, whi
solids) colorless liquids having characteristic odors. They have
ent boiling-points, various densities, great difference in their
and are most of them optically active.

Nearly every terpene has a known dextro- and lævoro
modification, from which an optically inactive form (p. 39) m
obtained by mixing equal parts of each. By repeated disti
or shaking with small amounts of concentrated sulphuric acid in
or polymeric terpenes are produced. On heating with iodine
yield cymene, $C_{10}H_{16}+2I=C_{10}H_{14}+2HI$, and on oxidation with
nitric acid they yield *p*-toluic acid, $C_6H_4(CH_3)(COOH)$, and
phthalic acid, $C_6H_4(COOH)_2$, which are also obtained on the ox
of cymene (p. 503). The terpenes inflame by the energetic actio
as well as by nitric acid. They also readily absorb

1. Terpenes.

, to which pinene, camphene, fenchene, belong, can take
mol. HCl, HBr, or Br_2 (p. 519); the terpanes, such as
ene, sylvestrene, can take up 2 mols. HCl, HBr, Br_2;
phellandrene and terpines take up only N_2O_3.
t 156°. *l*-Pinene, terebentene, occurs in the German,
ian turpentine oil, Canada balsam, incense, and many
'inene, or australene, occurs in English and American
l also in many ethereal oils. *i*-Pinene is produced

loride, $C_{10}H_{16}.HCl$, is produced by passing HCl gas into
stals having an odor similar to camphor, and is called
r."
is obtained from the turpentine, which exudes from
by distillation with water. It is a colorless liquid
dor boiling at 160° and which is insoluble in water but
ether, and fatty oils. It dissolves sulphur, phosphorus,
houc. On distilling with lime-water we obtain rectified
which is free from acids and resins. When exposed to
oil absorbs oxygen and becomes resinous (used in the
n varnishes and oil-paints).
ture of inactive terpenes, is produced by the action of
n turpentine oil and subsequently distilling with steam.
ne.
nes are produced by the action of alkalies upon *i*-, *d*-,
ride and are colorless crystals melting at about 50°,
ilar to camphor.
ained from fenchone (p. 524), boils at about 160°.
cture, p. 519) boils at 175°. *d*-Limonene, citrene, car-
hesperidene, smells like lemons and occurs in oil of dill,
owers, bergamot, and lemons.
urs with *l*-pinene in pine-needle oil.
pentene, cinene, boils at 180°, and is found with syl-
h and Russian turpentine oil, in camphor oils, and oil
s produced on heating the active limonenes to 300° or
er from terpine hydrate.
ormed by boiling terpine hydrate, terpineol, cineol, with
id. Boil at 185°.
he chief constituent of Swedish oil of turpentine, boils

arvestrene, is prepared synthetically.
oils at 170°. *d*-Phellandrene occurs in ethereal oil
nel, elemi, oil of eucalyptus; *l*-phellandrene also occurs
ntioned oils.
roduced by boiling most terpenes with dilute sulphuric
°, and smells like lemons.

2. Sesqui-, Di-, Polyterpenes.

nene, clovene, caryophyllene, santalene, are sesqui-
d occur in the ethereal oils of cubebs, savine, patchouli,
boil between 250°–280°.

ist of an indefinite amount of ethereal oils, etc., and a mixture of ns which are difficult of separation. Chemically they act like acids, y dissolve in alkalies, forming so-called resin soaps, which form a er like soaps and from which the resins are precipitated by acids. ey cannot be distilled without decomposition and they burn with a inous flame.

On fusion with alkalies most of the resins yield protocatechuic acid, loroglucin, paraoxybenzoic acid, pyrocatechin, resorcin, volatile fatty ids. With hot HNO_3 they give picric acid, phthalic acid, and finally alic acid On distillation with reducing agents, toluene, xylene, methyl-thracene, etc., are obtained.

The chief constituents of the resins are the resin esters (*resines*), resin cids (*resinolic acids*, e.g., abietic acid, $C_{19}H_{28}O_2$, and pimaric acid, $_{20}H_{30}O_2$), and indifferent aromatic compounds, *resenes*, of which little s known. The resin esters contain peculiar alcohols, the resin alcohols p. 526). These latter are divided into the colorless *resinols* and the olored *resinotannol*, which give the reactions for the tannins. Only a ew resins contain resines, resinolic acids, and resenes at the same time.

Hard resins are amorphous, generally hard and brittle, containing ittle or no ethereal oil, insoluble in water, soluble in alcohol, and most of them soluble in ether and ethereal oils. The solution of many resins in alcohol or turpentine is used as lacquer or varnish. The most common hard resins are common rosin or colophony, gum benzoin (contains benzoic acid), gum dammar, jalap resin, podophyllin, aloes (also contain aloin, p. 517), gum lac (purified shellac), amber (also contains ethereal oils and succinic acid), gum guaiac (contains also guaiacic acid and guaiac resin acid), and gum mastic.

Soft resins (balsams) are soft or semi-fluid and are mixtures of ethereal oils and resin. They are insoluble in water, soluble in alcohol and ether. As the ethereal oil absorbs oxygen the soft resins gradually become hard in the air. The most important are balsam of copaiba, turpentine, pine resin, and elemi resin.

The true balsams (balsam of Peru, p. 501, balsam of Tolu, p. 501, storax, p. 501) contain resin and ethereal oil only in small amounts and consist chiefly of aromatic acids, alcohols, and esters.

Gum resins are amorphous mixtures of gum, plant mucilage, resin, and ethereal oils. They are only partly soluble in water (the gum), and in alcohol (the resin). To this group belong gum ammoniacum, gum galbanum, gum asafœtida, gum gutta, gum euphorbium, gum olibanum, and gum myrrha.

Fossil resins. The most important are amber, which consists chiefly of a resinol ester of succinic acid, and asphalt, which is produced by the gradual oxidation of petroleum.

5. Cholesterins or Cholesterols

are the monohydric alcohols having the formula $C_{27}H_{46}O$, which are very widely distributed in the animal and plant kingdoms, and which were first discovered in the bile (χολή, bile; στερεός, solid). They are dextro- or lævorotatory and seem to be closely related to the terpenes or the camphors. They form odorless and tasteless crystals having various melting-points, are insoluble in water, dilute acids, and even in concen-

On boiling with dilute acids they split into glucose and *sapogenin*, $C_{14}H_{22}O_2$. The poisonous saponins are also called *sapotoxines*.

Scillain, scillitoxin, $(C_6H_{10}O_3)x$, in the squill (Bulbus scillæ); decom-oses into glucose, butyric acid, and isopropyl alcohol.

Xanthorhamnin, $C_{34}H_{42}O_{20}$, rhamnin, rhamnegin, in the fruits of vari-us varieties of rhamnus, and splits into rhamnetin (p. 542) and rham-inose, which can be split into rhamnose (p. 444) and galactose.

BITTER PRINCIPLES

e numerous bodies which consist only of C, H, and O, have a bitter ste, and are colorless or only faintly yellow in color and generally arkedly crystalline. They occur ready formed in the plants and m the active constituent of the same. Their behavior towards chemi-l agents is very diverse, and only a few combine with acids or bases. st of them are decomposed by these agents. Nearly all dissolve with ficulty in water, but dissolve easily in alcohol and ether. Their nstitution has not been sufficiently studied, but they all seem to long to the isocarbocylic compounds. Those of known constitu-n will be discussed with their mother-substances.

Agaricin, agaricic acid, $C_{16}H_{30}O_5+H_2O$, is obtained from the resin of e touchwood as a white amorphous or crystalline powder which melts 140°.

Angelicin, hydrocarotin, $C_{18}H_{20}O$, with angelic acid in the roots of ngelica archangelica; also in the carrot.

Arnicin, $C_{20}H_{30}O_4$, in the arnica-flowers.

Artemisin, $C_{15}H_{18}O_4$, with santonin in the worm-seed.

Acorin, acoretin, $C_{30}H_{60}O_6$, in the sweet flag.

Bryonin, $C_{48}H_{80}O_9$, in the roots of the bryony (Bryonia alba).

Euphorbon, $C_{15}H_{24}O$, in euphorbium resin.

Erythrocentaurin, $C_9H_{14}O_5$, in the centaury herb.

Hop bitter, $C_{25}H_{36}O_4$, in the strobiles of Humulus lupulus (lupulin).

Capsaicin, $C_9H_{14}O_2$, is the active principle of the Spanish pepper (Fruc-us capsici).

Cascarillin, $C_{12}H_{18}O_4$, in the Cortex cascarillæ.

Colombin, $C_{21}H_{22}O_7$, in the Radix colombo.

Kosin, kussin, $C_{22}H_{26}O_7$, in the Flores koso.

Pimpinellin, $C_{14}H_{12}O_5$, in the Radix pimpinellæ.

Picrotoxin, in the Cocculus indicus, consists of a mixture of *picro-toxinin*, $C_{15}H_{16}O_6$, and *picrotin*, $C_{15}H_{18}O_7$.

Podophyllotoxin, $C_{15}H_{14}O_6+2H_2O$, in Podophyllin.

Quassin, $C_{32}H_{42}O_{10}$, in quassia-wood (Lignum quassiæ).

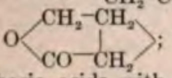
Urson, $C_{30}H_{48}O_3+2H_2O$, in the leaves of the bearberry (Folia Uvæ ursi).

III. HETEROCARBOCYCLIC COMPOUNDS.

CONSTITUTION.

The heterocarbocyclic compounds are those compounds whose olecule contains a ring-formed closed chain (an atomic ring) which composed of other atoms besides C atoms in the ring. Besides the eterocyclic compounds with one atomic ring we also know of those ith double or condensed atomic rings (p. 298).

All these compounds are in behavior quite similar to the isocarbo-clic compounds, and what has already been given in regard to these mpounds applies in general to the heterocarbocyclic compounds.

A complete separation of the heterocarbocyclic compounds from the phatic compounds is not rational, as a great many have out of necessity en discussed in connection with their aliphatic mother-substances, as ey can be obtained from these and also because they can be transformed to the aliphatic compounds. Of these compounds which have already en discussed with the aliphatic compounds we find the anhydrides of ny alcohols, acids, and their derivatives; e.g., ethylene oxide, $<\begin{matrix}CH_2\\CH_2\end{matrix}>O$, ccinic anhydride, $<\begin{matrix}CH_2-CO\\CH_2-CO\end{matrix}>O$; lactides, lactames, lactones, e.g., tyllactone,  $O\left<\begin{matrix}CH_2-CH_2\\ |\\ CO-CH_2\end{matrix}\right>$; imides, e.g., succinimide, $<\begin{matrix}CH_2-CO\\CH_2-CO\end{matrix}>NH$; lts of polybasic acids with polyvalent metals; e.g., lead malonate, $H_2<\begin{matrix}COO\\COO\end{matrix}>Pb$; also the di- and polyamines, e.g., ethylendiamine, $N<\begin{matrix}CH_2-CH_2\\CH_2-CH_2\end{matrix}>NH$; the imines, e.g., ethylenimine, $<\begin{matrix}CH_2\\CH_2\end{matrix}>NH$; the reids and purin derivatives, e.g., alloxan, $OC<\begin{matrix}NH-CO\\NH-CO\end{matrix}>CO$.

In the following pages the heterocarbocyclic compounds having and 6 atoms in the ring and having the same bondage as the toms of the benzene ring will be discussed. These rings, in con-radistinction to the rings with more or less atoms, cannot be uptured in a simple manner, but form compounds corresponding to the benzene compounds, from which the derivatives can be derived without a change in the atomic rings.

The addition products of the heterocarbocyclic compounds will be

1. Pyridine Compounds.

(structure, p. 536).
(methylpyridine, isomeric with aniline).
(dimethylpyridine, isomeric with toluidine).
N (trimethylpyridine, isomeric with xylidine).
N (tetramethylpyridine, isomeric with cumidine).

ses occur with quinoline bases and their isomers,
ar and in bone oil (see below). They are formed
n of many alkaloids and by heating aliphatic alde-
:

$$I_4O+NH_3=C_5H_2(CH_3)_3N+4H_2O.$$

ess poisonous liquids which are volatile without
which have a characteristic odor. The lower
soluble in water, while the higher members are
es of pyridine are readily oxidized into pyridine
537), while pyridine itself is not attacked by
r oxidizing agents, and by sulphuric acid only on
ure.

ri nes, $C_5H_5N(H_6)$, are called *piperidines*, methyl
pipecolines, the dimethyl piperidines, *lupetidines*, and
nes, *copelidines*, etc.
e mono derivatives are possible, which are desig-
nes, according as the substitution takes place near or
om Six biderivatives are possible, which are desig-
$\alpha\beta'$-, $\beta\gamma$-, $\beta\gamma'$-pyridines. Ten biderivatives with two
are possible (p. 467).
takes place at the N atom due to a rupture of the
pound is called *n*-pyridine.
pyridine is derived from its formation from quinoline.
dine carboxlyic acid on oxidation, when one benzene
similar to the oxidation of naphthalene (p. 514).
ned from this pyridine carboxylic acid by splitting off
e (p. 537).
il (Dippel's oil), is prepared from the crude animal
y distillation of bones and other animal substances
ontains chiefly pyridine bases, also quinoline bases,
gues (p. 544), nitriles of the fatty acids and benzene

C_5H_4N, corresponding to diphenyl (p. 504); we have
on oxidation yield nicotinic acids.
$I_4(OH)N$, correspond to the phenols and give a
ion with ferric chloride or they correspond to the

---

and are then called pyridones
done.
otinic acid, $C_5H_4(COOH)N$, β-pyr
the oxidation of nicotine (p. 554) an
HCl.
meronic acid, $C_5H_3(COOH)_2N$,
boxylic acids, is produced by the ox
honidine (p. 555).
Piperidine, $C_5H_{10}NH$ or $H_2C<\begin{matrix}CH_2-CH\\CH_2-CH\end{matrix}$
is produced by the action of nascen
colorless, alkaline liquid having a pep
pared from the alkaloid piperine (p. 55
ridine is the mother-substance of the
solanum alkaloids (p. 557).
Propylpiperidine, $C_5H_9(C_3H_7)NH$, is pro
upon allyl py ine, and is an inactive
laevo and a dextro modification. Th
(p. 554).
Eucain B, $C_5H_6(CH_3)_3(\cdot O\cdot C_6H_5\cdot CO)-NH$
trimethyl oxypiperidine (also call
is used as a local anæsthetic instead
Euphthalmin, $C_5H_6(CH_3)_3(\cdot O\cdot C_6H_5\cdot CHO$
of phenyl glycolyl-*n*-methyl-trime
mandelic acid radical, p. 498), dil
instead of atropine.

2. Quinoline Com

Quinoline, C_9H_7N (str
Isoquinoline, C_9H_7N (st
Quinaldine, $C_{10}H_9N$ (α
Lepidine, $C_{10}H_9N$ (γ
Cryptidine, $C_{11}H_{11}N$ (

These quinoline or benzopyridin
in bone oil (p. 538) and in co
(p. 543) by distillation w
540).

They are liquids having peculi
water. Oxidizing agents, iod
benzene nucleus and not upo
the double bonds in quinolin
ducing the hydroquinolines

Two isomerides of quinoline
the N atom exists beside o

4. Pyrone Compounds.

α-Pyrone, coumalin, $C_5H_4O_2$ or $O<\genfrac{}{}{0pt}{}{CO-CH}{CH=CH}>CH$, is a colorless, neu- al liquid, boiling at 209°, and having an odor similar to caraway seeds. is produced by heating coumalic acid (see below).

γ-Pyrone, pyrocomane, $O<\genfrac{}{}{0pt}{}{CH=CH}{CH=CH}>CO$, forms colorless, neutral rystals which melt at 32°. The pyrones and their derivatives on warming vith NH_3 are converted into pyridones (p. 539), when the oxygen of the ing is replaced by =NH. The properties of many pyrones is peculiar, specially dimethyl pyrone, $C_5H_2(CH_3)_2O_2$, which although it has a neu- ral reaction, forms salts with acids directly by addition, similar to am- nonia. In these salts for every hydrogen atom of the acid one molecule f the pyrone compound takes its place. On account of their analogy o the ammonium salts (pp. 150 and 216) these salts are called *oxonium alts* and we must admit that the formation of salts is caused by the xygen in the ring being tetravalent; thus, $\genfrac{}{}{0pt}{}{H}{Cl}>O<\genfrac{}{}{0pt}{}{CH=CH}{CH=CH}>CO$, di- nethyl pyrone hydrochloride.

According to more recent researches numerous other cyclic and ali- hatic compounds containing oxygen have the property of forming lts such as the oxonium salts.

The same property has been known for a long time in certain sulphur mpounds, the sulphonium or sulphin hydroxides (p. 352), where the lphur atom appears tetravalent.

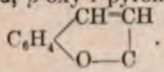
Comanic acid and **coumalic acid,** both $C_5H_3(COOH)O_2$, are pyrone- rboxylic acids. The first is produced from chelidonic acid (see below) d the other from malic acid by heating with concentrated sulphuric id.

Chelidonic acid, $C_5H_2(COOH)_2O_2$, pyrone-dicarboxlic acid, occurs the Chelidonium majus, and yields on heating comanic acid and then pyrone.

Meconic acid, $C_5H(OH)(COOH)_2O_2$, oxypyrone-dicarboxylic acid, occurs opium, and on boiling with water it splits off CO_2 and is converted into

Comenic acid, oxypyrone-carboxylic acid, $C_5H_2(OH)(COOH)O_2$; this lits off more CO_2 on heating and yields

Pyromeconic acid, β-oxy-r-pyrone, $C_5H_3(OH)O_2$.

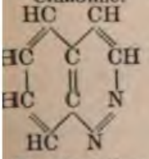
α-Benzopyrone, . Coumarin (p. 501) is to be con- dered as α-benzopyrone.

Xanthone, $C_{13}H_8O_2$, diphenylenkentone oxide, is the mother sub- tance of *euxanthon*, $C_{13}H_8O_4$, and of *euxanthic acid*, $C_{19}H_{18}O_{11}$, both ccurring in Indian yellow (p. 446), and also of the yellow plant pig- nent *gentisin*, $C_{14}H_{10}O_5$, of the gentian root and *datiscetin*, $C_{15}H_{12}O_6$; also f *rhamnochrysine*, $C_{18}H_{12}O_7$, and *rhamnocitrine*, $C_{13}H_{10}O_5$ (see below).

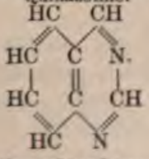
Flavone, $C_{15}H_{10}O_2$, is the mother-substance of numerous yellow plant pigments, for example, *quercetin*, $C_{15}H_{10}O_7$, from the glucoside quercitrin; *fisetin*, $C_{15}H_{10}O_6$, in the fustic wood; *chrysine*, $C_{15}H_{10}O_4$, in the buds of the various poplars; *luteolin*, $C_{15}H_{10}O_6$, in Reseda luteola and digitalis leaves; *galangin*, $C_{15}H_{10}O_5$, and *campferid*, $C_{16}H_{12}O_6$, in the galanga root; *morin*,

iperazine, $C_4H_{10}N_2$ or $HN<\substack{CH_2-CH_2\\CH_2-CH_2}>NH$, diethylendiamine, is a hydropyrazine. It is obtained from ethylene bromide by the action thylendiamine, and forms crystals which are soluble in water and t at 106° and which dissolve large quantities of uric acid. Spermine stals (Schreiner's crystals), found in semen, seem to be closely re-d to piperazine.

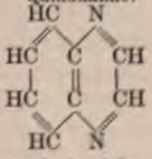
Benzortho-
iazine, $C_8H_6N_2$,
Cinnoline.



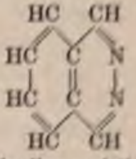
Benzometa-
diazine, $C_8H_6N_2$,
Quinazoline.



Benzopara-
diazine, $C_8H_6N_2$,
Quinoxaline.

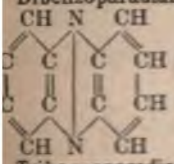


Phthalazine,
$C_8H_6N_2$.



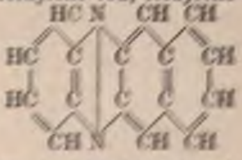
The first three of these four isomers are derived from quinoline and the t from isoquinoline, where one $-CH-$ group is replaced by $-N-$. Quin-oline is only known in the form of derivatives, while the others form stals having strong basic properties.

Phenyldihydroquinazoline, $C_6H_5(C_8H_5)N_2(H_2)$. Its compound with HCl used in medicine under the name orexin.



Dibenzoparadiazine, phenazine, $C_{12}H_8N_2$, is derived from acridine, where one $-CH-$ group is replaced by $-N-$. It is found in coal-tar and forms yellow needles and by the introduction of amido-, alkyl-, or alphyl groups forms the dyes called indolines (true blue), nigrosines (aniline black), safranines (indoin blue, mauvein, magdala red, indazin blue), toluylene red, toluylene blue, Janus green.

Tribenzoparadiazine, naphthophenazine, $_6H_{10}N_2$, obtained from certain azo compunds, forms colorless crystals and by the in-oduction of amido-, alphyl-, or alkyl groups rms the dyes called eurhodoles, eurhodines, indulines (azocarmin).

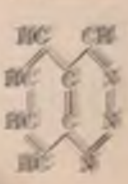


-Triazine, $HC<\substack{N-CH\\N-CH}>N$, $C_3H_3N_3$, cyanidine, corresponds to tri- cyanic acid and is the mother-substance of the cyanuric compounds 352).

o-Triazine, $HC<\substack{N=CH\\CH-N}>N$, as well as

v-Triazine, $HC<\substack{CH-N\\CH-N}>N$, is only known in the form of derivatives.

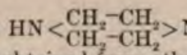
regard to the meaning of a- s-, [illegible] page 469.



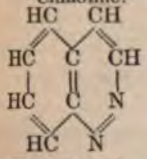
Phentriazine, $C_7H_5N_3$, is p[illegible] from quinoline, H_7N, by replacing two $-CH-$ [illegible] $-N-$ atoms. [illegible] crystals which [illegible] have a nar-

$\substack{N=N\\CH-N}>N$, as [illegible] isomers is

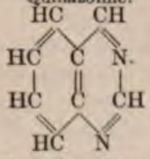
[illegible] derivatives are

Piperazine, $C_4H_{10}N_2$ or  $HN{<}\genfrac{}{}{0pt}{}{CH_2-CH_2}{CH_2-CH_2}{>}NH$, diethylendiamine, is a hexahydropyrazine. It is obtained from ethylene bromide by the action of ethylendiamine, and forms crystals which are soluble in water and melt at 106° and which dissolve large quantities of uric acid. Spermine crystals (Schreiner's crystals), found in semen, seem to be closely related to piperazine.

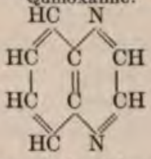
Benzorthodiazine, $C_8H_6N_2$, Cinnoline.



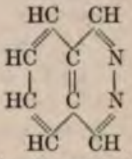
Benzometadiazine, $C_8H_6N_2$, Quinazoline.



Benzoparadiazine, $C_8H_6N_2$, Quinoxaline.



Phthalazine, $C_8H_6N_2$.



The first three of these four isomers are derived from quinoline and the last from isoquinoline, where one $=CH-$ group is replaced by $=N-$. Quinazoline is only known in the form of derivatives, while the others form crystals having strong basic properties.

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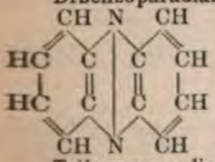
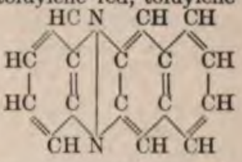
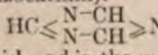
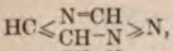
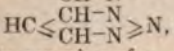


Tribenzoparadiazine, naphthophenazine, $C_{16}H_{10}N_2$, obtained from certain azo compounds, forms colorless crystals and by the introduction of amido-, alphyl-, or alkyl groups forms the dyes called eurhodoles, eurhodines, rosindulines (azocarmin).



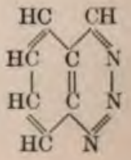
s-**Triazine,**  $HC{\leqslant}\genfrac{}{}{0pt}{}{N-CH}{N-CH}{\geqslant}N$, $C_3H_3N_3$, cyanidine, corresponds to trihydrocyanic acid and is the mother-substance of the cyanuric compounds (p. 382).

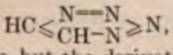
a-**Triazine,**  $HC{\leqslant}\genfrac{}{}{0pt}{}{N=CH}{CH-N}{\geqslant}N$, as well as

v-**Triazine,**  $HC{\leqslant}\genfrac{}{}{0pt}{}{CH-N}{CH-N}{\geqslant}N$, is only known in the form of derivatives.

In regard to the meaning of *s*-. *a*-, *v*-, see page 469.

Phentriazine, $C_7H_5N_3$, is produced from quinoline, C_9H_7N, by replacing two $=CH-$ groups by two $=N-$ atoms. It forms yellow crystals which melt at 75° and have a narcotic odor.



Tetrazine,  $HC{\leqslant}\genfrac{}{}{0pt}{}{N=N}{CH-N}{\geqslant}N$, as well as its isomers is not known free, but the derivatives are known.

2. Oxazine and Thiazine Compounds.

Oxazine, $O<\begin{matrix}CH=CH\\CH=CH\end{matrix}>NH$, is not known free.

Tetrahydo-paraoxazine, $O<\begin{matrix}CH_2-CH_2\\CH_2-CH_2\end{matrix}>NH$, morpholin, is a colorless, basic fluid, boiling at 129° and which has great similarity to piperidine (p. 539). It is the mother-substance of the alkaloids morphine, codeine, and thebaine (see Alkaloids).

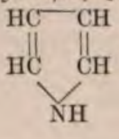
Phenoxazine, $C_6H_4<\begin{matrix}NH\\O\end{matrix}>C_6H_4$, forms colorless leaves and by the introduction of alkylamine groups it forms the oxazine and oxazone dyes (Nile blue and gallocyanin), the blue muscarin pigment.

Phenthiazine, thiodiphenylamine, $C_6H_4<\begin{matrix}NH\\S\end{matrix}>C_6H_4$, is produced from diphenylamine by heating it with sulphur and forms yellow scales. By the introduction of alkyl or amido groups it forms the thionin dyes, for example, Lauth's violet, methylene blue, methylene green, thiazine red, and thiazine brown, thionin blue and toluidine blue.

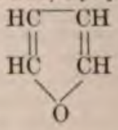
FIVE-MEMBERED COMPOUNDS WITH ONE OTHER ATOM IN THE CARBON RING.

These contain the tetrol group, C_4H_4, which with $^-NH^-$, $^-O^-$, or $^-S^-$ form a closed chain:

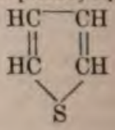
Pyrrol, C_4H_5N.



Furane, C_4H_4O.



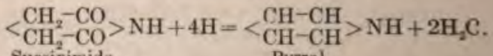
Thiophene, C_4H_4S.



The preparation and properties of the derivatives of these compounds are the same as the corresponding benzene derivatives.

1. Pyrrol Compounds.

Pyrrol, C_4H_5N, occurs in coal-tar and in bone-oil, is produced by heating succinimide with zinc dust and water:



$$<\begin{matrix}CH_2-CO\\CH_2-CO\end{matrix}>NH+4H=<\begin{matrix}CH-CH\\CH-CH\end{matrix}>NH+2H_2C.$$

Succinimide. Pyrrol.

It is a colorless basic liquid boiling at 130° and having an odor similar to chloroform and chemical properties similar to pyridine. Its vapors color a pine shaving moistened with HCl purple-red.

If in pyrrol the hydrogen attached to a carbon atom or to a ni tom be replaced by alkyls, we obtain the homologues of pyrrol, the p ases, which are also found in bone-oil and are faintly basic liquids; nethyl pyrrol, $C_4H_4=N-CH_3$, homopyrrol, $C_4H_3(CH_3)=NH$, ethylpy $C_4H_4=N-C_2H_5$, dimethylpyrrol, $C_4H_2(CH_3)_2=NH$.

Tetraiodopyrrol, iodol, C_4I_4NH, forms a yellow powder which is u as an antiseptic.

Pyrroline, dihydropyrrol, C_4H_7N or $<\begin{matrix}CH_2-CH_2\\CH=CH\end{matrix}>NH$, and

Pyrrolidine, C_4H_9N, or $<\begin{matrix}CH_2-CH_2\\CH_2-CH_2\end{matrix}>NH$, tetrahydropyrrol, are produced by the addition of hydrogen to pyrrol. Pyrrolidine is the mother-substance of most of the coca and solanum alkaloids.

Pyrrolidine carbonic acid, $C_4H_8(COOH)N$, is a cleavage product of the protein bodies.

Chlorophyll, the pigment of the green parts of plants, consists of C, H, O, N, P, perhaps also iron, and up to the present time is obtained more or less ecomposed as soft masses which are soluble with a bluish-green color in lcohol, ether, fatty and ethereal oils. It is decomposed by acids to *hylloxanthin* and then from this into *phyllocyanin*, which on heating ith alkalies yields *phylloporphyrin*, $C_{16}H_{18}N_2O$, and this, like the hæmato- orphyrin obtained from hæmoglobin, is reducible to hæmopyrrol (iso- utyl pyrrol).

Blood-pigments. The color of the blood is produced by the chromo- roteids oxyhæmoglobin and hæmoglobin, which are compounds of the olorless proteid globin with the pigments hæmatin or hæmochromogen. losely related to these are the pigments of the bird's-egg shells, the blue *ocyanin*, the reddish *oorhodin*, the green *oochlorin*, and the yellow *oo.xan- hin.*

Hæmatin, $C_{34}H_{34}N_4FeO_5$, the cleavage product of oxyhæmoglobin p. 565), is a bluish-black amorphous powder soluble with a red color in cidified alcohol, and on oxidation yields two bibasic *hæmatinic acids*, $C_8H_{10}O_5$. On treatment with concentrated sulphuric acid or hydrochloric cid it is converted into hæmatoporphyrin (see below). Hæmatin gives a haracteristic absorption spectrum (p. 45).

Hæmin, $C_{34}H_{32}N_4FeO_4 \cdot HCl$, hæmatin hydrochloride, Teichmann's lood-crystals, serve in the detection of small amounts of blood. The bject containing the blood is extracted with a little cold water and this extract allowed to evaporate on a glass slide and warmed with a trace of salt and a few drops of glacial acetic acid. On cooling, the characteristic bluish-black rhombic crystals of hæmin are seen under the microscope.

Hæmochromogen, $C_{64}H_{70}Fe_2N_{10}O_7$, the cleavage product of hæmoglobin (p. 566), forms dark crystals which are soluble in alkalies yielding a red solution, and then quickly absorb oxygen, forming hæmatin. In acid solution hæmatoporphyrin is produced. It also gives a characteristic absorption spectrum.

Hæmatoporphyrin, $C_{32}H_{36}N_4O_6$, the cleavage product of hæmatin and hæmochromogen (which see) and also often found in the urine, forms a brown amorphous powder soluble with a red color in dilute acids and ives a characteristic absorption spectrum. On oxidation it yields the ibasic *biliverdic acid*, $C_8H_9NO_4$, and on reduction it yields like *phyllo- rphyrin* (the cleavage product of chlorophyll) and hæmopyrrol (isobutyl rrol).

yrrol, C_8H_7N, is formed on fusing proteids with caustic
s in the putrefaction of the same and hence is found in
obtained by the distillation of oxindol with powdered
heating orthonitrocinnamic acid with caustic alkali and

$$\begin{matrix}CH=CH-COOH\\NO_2\end{matrix}=C_6H_4<\begin{matrix}CH\\NH\end{matrix}>CH+CO_2+O_2.$$

s, faintly basic scales having feces-like odor and which are
with steam. It can be obtained from feces, accompanied
nd phenols contained therein, by distillation with water.
shaving moistened with HCl cherry-red.
H_7NO (see p. 468), obtained by the action of sodium
isatin (see below) in acid solution. It forms colorless
by reduction are converted into indol, C_8H_7N, and are
dioxindol (see below) by oxidation in the air.
e indican, C_8H_7NO, isomer of oxindol, occurs as potassium
e, $C_8H_6N(O-SO_2-OK)$, in small amounts in the urine of
arger amounts in herbivorous urine. If urine is carefully
idizing substances the indoxyl sulphuric acid is oxidized
which can be shaken out by chloroform, giving a blue color
On stronger oxidation it yields isatin.

From aniline and chloracetic acid we obtain anilido-
nylglycocoll), which on fusion with alkali hydroxides yields

$$_5-NH)CH_2-COOH=H_2O+C_6H_4<\begin{matrix}C(OH)\\NH-\end{matrix}>CH.$$

Yellow crystals soluble in water, alcohol, ether, etc.,
t 85°. In alkaline solution it is oxidized into indigo-blue,
r.

acid, $C_9H_7NO_3$ or $C_8H_6(COOH)NO$. *Preparation.* Brom-
ester and aniline yield anilido-malonic acid ester:

$$\begin{matrix}C_2H_5\\C_2H_5\end{matrix}+C_6H_5\cdot NH_2=C_6H_5\cdot NH\cdot CH<\begin{matrix}COO\cdot C_2H_5\\COO\cdot C_2H_5\end{matrix}+HBr,$$ which

alcohol and indoxylic acid ester, $C_6H_5\cdot NH\cdot CH<\begin{matrix}COOC_2H_5\\COOC_2H_5\end{matrix}=$
$)>C\cdot COO\cdot C_2H_5+C_2H_5OH$. This on oxidation in alkaline
the air turns into indigo-blue: $2C_9H_6(C_2H_5)NO_3+O_2=$
$2CO_2+2C_2H_5OH$.
he technical preparation of indigo (p. 548).

. Colorless prisms which are oxidized into indigo-blue and
ield indoxyl and CO_2.

l, $C_8H_7NO_2$, is produced by the action of sodium amalgam
aline solution of isatin. It forms colorless prisms and is
zed in watery solution into isatin.

H_5NO_2, formed in the oxidation of indigo by nitric acid as
prisms soluble in hot water and alcohol. It is artificially
n orthonitrophenyl propiolic acid by boiling with alkalies
58).

er, dilute acids, and alkalies. It is soluble in chloroform, aniline, oil turpentine, paraffin, phenol, and benzene. On fusion with alkali hy- oxides, indoxyl, salicylic acid, anthranilic acid (*o*-amidobenzoic acid), d aniline are obtained according to the temperature. On oxidation it elds isatin, and on reduction we obtain indigo white. It dissolves in ery concentrated or better in fuming sulphuric acid, forming

Indigomonosulphonic acid, $C_{16}H_9N_2O_2(SO_3)H$, and

Indigodisulphonic acid, $C_{16}H_8N_2O_2(SO_3\cdot H)_2$, which are used in the dyeing f wool. Its sodium salt, $C_{16}H_8N_2O_2(SO_3\cdot Na)_2$, which is soluble in water with a blue color, is called *indigo carmine*.

Indirubin, indigo purpurin, $C_{16}H_{10}N_2O_2$, an isomer of indigo blue, occurs in commercial indigo blue, and is produced besides indigo blue on the decomposition of the indoxyl sulphuric acid of the urine by HCl. It forms brownish-red shining needles.

Indigo white, $C_{16}H_{12}N_2O_2$, is produced from indigo blue by reduction with ferrous sulphate or grape-sugar in alkaline solution. The indigo and these substances are mixed with water and filled completely into a flask, which is closed and allowed to stand (indigo of the dyer). The yellow solution obtained is treated with HCl, the air being excluded, when the indigo white precipitates as a white crystalline powder, which is oxidized to indigo blue in the air (preparation of pure indigo blue from the commercial indigo). Indigo white, in contradistinction to indigo blue, dissolves in alcohol, ether, and alkalies. This last property is made use of in dyeing.

The dyeing is done according to two methods: The material to be dyed is dipped in an aqueous solution of indigo sulphonic acid (Saxon-blue dyeing), or the material is dipped in the indigo solution as above described, and then exposed to the air, when the indigo white is oxidized to indigo blue, which deposits in the tissues.

3. Furane Compounds.

Furane, furfurane, tetrol, C_4H_4O, or $<\genfrac{}{}{0pt}{}{CH=CH}{CH=CH}>O$, occurs in the first distillate of pinewood-tar and in the distillation of pyromucic acid, $C_5H_4O_3$, with soda-lime. It is a neutral fluid, insoluble in water, boiling at 32°, and having a peculiar odor. It colors a pine chip moistened with HCl green.

Furanalcohol, $C_4H_3(CH_2OH)O$, found in the products obtained on roasting coffee, is prepared from its aldehyde. It is a colorless liquid boiling at 170°.

Furol, furanaldehyde, furfurol, $C_4H_3(CHO)O$, a decomposition product of certain proteids, occurs in beer and brandy, and is produced in the distillation of bran (furfur), seaweeds, pentoses, and pentosanes (p. 444) with dilute sulphuric acid. It is a colorless aromatic liquid boiling at 162°, and which turns brown in the air. Sesame-oil is colored cherry-red by HCl and an alcoholic solution of furfurol (use of furfurol in the detection of margarine, which in Germany must contain sesame-oil).

Pyromucic acid, furancarboxylic acid, $C_4H_3(COOH)O$, is obtained by the oxidation of furol as well as in the dry distillation of mucic acid, $C_6H_{10}O_8$. It forms colorless needles which melt at 134°.

Furoïn, $C_4H_3O-CO-CH-OH-C_4H_3O$, is produced from furol in a manner similar to benzoïn from benzaldehyde (p. 488). It melts at 135°.

Benzofurane, coumarone, $C_6H_4<\genfrac{}{}{0pt}{}{CH}{O—}>CH$, bears the same relationship to furane as indol bears to pyrrol. It occurs with its homologues in coal-tar and is an indifferent oily liquid.

4. Thiophene Compounds.

Thiophene, C_4H_4S or $<\genfrac{}{}{0pt}{}{CH=CH}{CH=CH}>S$, occurs with methylthiophene (thiotolene) and dimethylthiophene (thioxene) to a slight extent in the light oils of coal-tar (p. 473) and therefore occurs in crude benzene.

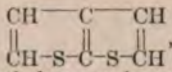
It is produced by heating succinic anhydride with P_2S_3:

$$<\genfrac{}{}{0pt}{}{CH_2-CO}{CH_2-CO}>O+P_2S_3=<\genfrac{}{}{0pt}{}{CH=CH}{CH=CH}>S+P_2O_3+S_2,$$

or by passing acetylene through boiling sulphur: $2C_2H_2+S=C_4H_4S$. It is a colorless neutral liquid boiling at 84°, which with isatin and sulphuric acid forms blue indophenin, $C_{12}H_7NOS$ (delicate reaction for thiophene).

Thiophenic acid, $C_4H_3(COOH)S$, very similar to benzoic acid, is, like all thiophene derivatives, known as two isomers (α and β).

Benzothiophene, thionaphthene, $C_6H_4<\genfrac{}{}{0pt}{}{CH}{S—}>CH$, bears the same relation to thiophene that benzofurane does to furane. It forms colorless crystals.

Thiophtene,  , is related to thiophene in the same manner as naphthalene to benzene, and is produced by heating citric acid with P_2S_3. It forms a thick liquid boiling at 225°.

FIVE-MEMBERED COMPOUNDS CONTAINING SEVERAL OTHER ATOMS IN THE CARBON RING.

The most important compounds of this group are those containing nitrogen, which are derived from pyrrol, furane, thiophene, indol derivatives by replacing =CH− groups by =N− atoms. They are called *azoles*, and according to the number of N atoms in the ring di-, tri-, tetrazoles. *Oxazoles* contain one N and one O atom; *thiazoles*, one N and one S atom in the ring. According as the N atoms occupy the *o*-, *m*-, or *p*-position to each other they are called *oiazoles*, *miazoles*, and *piazoles* (p. 542).

1. Azole Compounds.

Glyoxaline, $C_3H_4N_2$ or $<\genfrac{}{}{0pt}{}{CH=CH}{N==CH}>NH$, *m*-diazole, imidazole, and

Pyrazole, $C_3H_4N_2$ or $<\genfrac{}{}{0pt}{}{CH=CH}{CH==N}>NH$, *o*-diazole, form colorless crystals.

Dihydrypyrazole, pyrazoline, $<\genfrac{}{}{0pt}{}{CH_2-CH_2}{CH===N}>NH$, is a basic liquid.

Tetrahydropyrazole, pyrazolidine, $<\genfrac{}{}{0pt}{}{CH_2-CH_2}{CH_2-NH}>NH$, is only known in the form of derivatives.

thyldihydroimidazole, ethylenethylenyldiamine, **lysidin,** $\begin{matrix}-CH_2\\(CH_3)\end{matrix}>NH$, is used as a solvent for uric acid.

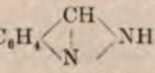
razolon, $<\begin{matrix}CH_2-CO\\CH=N\end{matrix}>NH$, pyrazolin ketone, forms colorless crystals the mother-substance of
enyldimethylpyrazolon, antipyrine,

$$C_{11}H_{12}N_2O \text{ or } <\begin{matrix}CH\overline{\qquad\qquad}CO\\C(CH_3)-N(CH_3)\end{matrix}>N(C_6H_5),$$

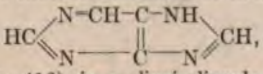
luced by warming methylphenylhydrazine with acetoacetic ester, a peculiar rearrangement in the pyrazolon ring takes place:

$$\underset{\text{Methylphenyl-hydrazine.}}{C_6H_5\cdot N_2H_2\cdot CH_3}+\underset{\text{Aceto-acetic ester.}}{C_6H_{10}O_3}=\underset{\text{Antipyrine.}}{C_{11}H_{12}N_2O}+H_2O+\underset{\text{Alcohol.}}{C_2H_6O}.$$

white crystalline powder, melting at 113° and readily soluble in and alcohol. Its dimethylamido derivative is called pyramidon, its salicylic acid salt is called acopyrine or acetopyrine.
ipyrine, $C_{11}H_{12}N_2O(C_6H_4\cdot OH\cdot COOH)$, forms a white sweetish micro-line powder or plates, which are not readily soluble in water, but soluble in alcohol. It melts at 92°.

azole, $C_7H_6N_2$ or  NH, benzopyrazole, and its isomer,

ndazole, $C_7H_6N_2$ or $C_6H_4<\begin{matrix}CH\\NH\end{matrix}>N$, is indol, in which one $=CH-$ is replaced by a $=N-$ atom. They form crystals having weak basic ties and are the mother-substance of many compounds.

rin, $C_5H_4N_4$ or  CH, the mother-substance of ic acid group (p. 416), is a diazindiazole which may be considered zopyrrol, C_8H_7N (p. 547), in which three $=CH-$ groups are replaced ee $=N-$ atoms.

otriazole, $C_2H_3N_3$ or $<\begin{matrix}CH=N\\CH=N\end{matrix}>NH$, pyrro (*aa'*) diazole, forms ss crystals which melt at 22°;

rrodiazole, $C_2H_3N_3$ or $<\begin{matrix}CH=CH\\N=N\end{matrix}>NH$, pyrro (*ab*) diazole, melts at

azole, $C_2H_3N_3$ or $<\begin{matrix}N=CH\\N=CH\end{matrix}>NH$, pyrro (*bb'*) diazole, melts at 121°, derived from pyrrol, C_4H_4N, by substituting two $=CH-$ groups by toms, and hence are called pyrrodiazoles. They with their deriva-re weak bases.

razole, CH_2N_4 or $<\begin{matrix}CH=N\\N=N\end{matrix}>NH$, forms crystals which melt at aving an acid character. Its salts explode.

ith the exception of nicotine are difficultly soluble in water. The olutions have a bitter taste and an alkaline reaction. They have e character of amine bases and combine, like these, with acids by ddition, forming good crystalline salts, which are soluble in water and lcohol and insoluble in ether with the exception of colchicine. The ree alkaloid is precipitated from the aqueous solution of its salts by lkali hydroxides and alkali carbonates. They are mostly optically ctive and indeed lævorotatory. Coniine, quinidine, cinchonine, ilocarpine, are dextrorotatory, and piperine, papaverine, berberine, nd atropine are inactive.

They are precipitated from their solution by tannic acid, phospho-molybdic acid, and phospho-tungstic acid (p. 271), potassium-mer-curic iodide, potassium-cadmium iodide, and a great many by iodine. Their hydrochloric acid compounds are precipitated by platinum chloride as a double crystalline salt, similar to ammonium salts (p. 317) and amine bases.

In preparing them the parts of the plants are extracted with dilute ydrochloric acid. The volatile alkaloids can be obtained from this olution by distillation with caustic alkali. In order to separate the on-volatile alkaloids the solution is generally first precipitated by ead acetate in order to remove tannin bodies, pigments, and gluco-ides, and the filtrate freed from lead by H_2S, and the alkaloids pre-ipitated from this filtrate by caustic alkalies. This precipitate is issolved in alcohol and repeatedly recrystallized.

1. Pyridine and Pyrrol Compounds.

Trigonelline, $C_7H_7NO_2+H_2O$, nicotinic acid methyl betaine (pp. 369 nd 539), occurs in the seeds of Trigonella fœnumgræcum, and the seeds f Strophantus hispudus. It forms neutral prisms.

Hygrine, $C_8H_{15}NO$, $C_4H_7(CH_3)(CO \cdot C_2H_5)$, methylpyrrolidine ethyl etone, forms a liquid which turns brown in the air and which occurs to slight extent in coca leaves (p. 558).

Piperine, $C_{17}H_{19}NO_3$, piperylpiperidine, occurs in ordinary and long epper, decomposes on boiling with alkali hydroxides into piperic acid $_{12}H_{10}O_4$ (p. 501), and piperidine, $C_5H_{10}NH$ (p. 539).

Pilocarpine, $C_{11}H_{16}N_2O_2$, **pilocarpidine,** $C_{10}H_{14}N_2O_2$, **jaborine,** $C_{22}H_{32}N_4O_4$, ccur together in the leaves of Pilocarpus pennatifolius. Pilocarpine is oluble with a green color in fuming nitric acid and blackens on rubbing with an equal quantity of mercurous chloride and moistening with alcohol.

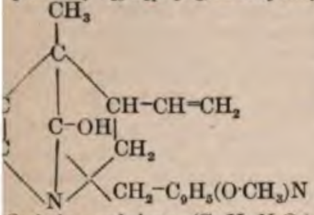
Pilocarpine hydrochloride, $C_{11}H_{16}N_2O_2 \cdot HCl$, forms crystals which melt t 194°.

Arecaidine, $C_7H_{11}NO_2$, tetrahydromethyl nicotinic acid (p. 539), **areco-ine,** $C_8H_{13}NO_2$ (methylarecaidine), **guvacine,** $C_6H_9NO_2$, (tetrahydromethyl-y are derivatives of a quinoline and a complicated piperidine ring Quinine).

Quinine and quinidine are readily soluble in ether, cinchonine and chonidine are nearly insoluble therein. If to an aqueous solution of a nine or quinidine salt we add chlorine water and then ammonia we ain a beautiful emerald-green coloration.

Cinchonine, $C_{19}H_{22}N_2O$ (structure, see Quinine), forms bitter prisms ich are difficultly soluble in alcohol and which melt at 255°.

Quinine, $C_{20}H_{24}N_2O_2$, methyloxylcinchonine, exists to about 6 per cent. in the cinchona bark, forms with $3H_2O$, shining bitter needles which are difficultly soluble in alcohol. When anhydrous they melt at 175°. It forms primary and secondary salts, which latter are nearly insoluble in water.



Quinine bisulphate, $(C_{20}H_{24}N_2O_2)H_2SO_4+7H_2O$, forms colorless crystals which dissolve in 10 parts water.

Quinine sulphate, $(C_{20}H_{24}N_2O_2)_2H_2SO_4+8H_2O$, is not readily soluble in ter but more soluble than the bisulphate by the addition of some phuric acid.

Quinine hydrochloride, $C_{20}H_{24}N_2O_2{\cdot}HCl+2H_2O$, white crystalline dles, soluble in 34 parts water.

Quinine-iron citrate is readily soluble in water.

Quinine tannate, yellow amorphous powder soluble with difficulty.

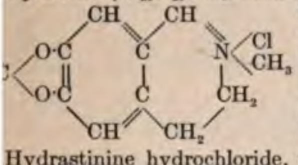
Quinine carboxylic acid ethyl ester, $C_{20}H_{23}(COO{\cdot}C_2H_5)N_2O_2$, *euquinine*, ves as a tasteless substitute for quinine.

Cinchonidine, $C_{19}H_{22}N_2O$, the stereiosomer of *cinchonine*, also obtained n cinchonine by rearrangement of the molecule, forms large prisms ich melt at 203° and are readily soluble in alcohol.

Quinidine, $C_{20}H_{24}N_2O_2$, methyloxylcinchonidine, forms prisms with molecules H_2O and when anhydrous melts at 172°.

3. Isoquinoline Compounds.

Hydrastine, $C_{21}H_{21}NO_6$, occurs in Hydrastis canadensis (Golden seal), forms prisms melting at 132° and on oxidation yields opianic acid, $C_{10}H_{10}O_5$ (p. 497), and



Hydrastinine, $C_{11}H_{13}NO_3$. The salts of this contain the complex $C_{11}H_{11}NO_2$ which is obtained by the removal of water.

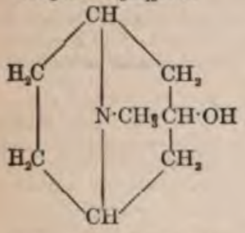
Hydrastinine hydrochloride, $C_{11}H_{11}NO_2{\cdot}HCl$ (see structural formula). This forms yellow needles which melt at 210° and are soluble in water h a blue fluorescence.

Berberine, $C_{20}H_{17}NO_4$, contains a hydrastinine and an isoquinoline with a mutual C and N atom. It occurs in the varieties of Berberis, in columbo root, in the Hydrastis canadensis, in the bark of the Geoffroya aicensis, Xanthoxylum clava, and many other plants used as a yellow . It forms yellowish-brown, optically inactive needles with 6 molees H_2O. It melts at 145°.

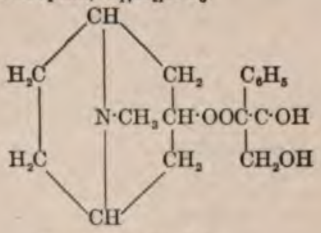
5. Pyrrolidine-Piperidine Compounds.

The Solanaceæ alkaloids, atropine, hyoscyamine, belladonine, scopol-ine, also the coca alkaloids, cocaine and tropacocaine, contain a methyl-d pyrrol ring (p. 544) in combination with a piperidine ring (p. 539). ey may also be considered as a seven-carbon ring (cycloheptane) with so-called nitrogen bridge. The mother-substance of these alkaloids is opine, which is evident from the following formulæ:

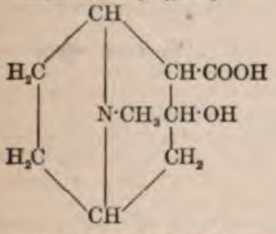
Tropine, $C_8H_{15}NO$.



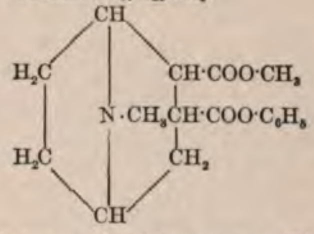
Atropine, $C_{17}H_{21}NO_3$.



Ecgonine, $C_9H_{15}NO_3$.



Cocaine, $C_{17}H_{21}NO_4$.



Atropine, belladonine, hyoscyamine, scopolamine, cause a dilation the pupils even in the smallest quantities. When a trace of these dies is warmed with concentrated sulphuric acid and some water and tassium permanganate added, an odor similar to oil of bitter almonds developed. If a trace is dissolved in concentrated H_2SO_4 and some dium nitrate added an orange coloration is obtained which turns reddish let and then pale pink when treated with an alcoholic caustic alkali ution.

Atropine and hyoscyamine are stereoisomers and decompose on heat-g with bases into tropine and tropic acid (p. 502):

$$C_{17}H_{23}NO_3 + H_2O = \underset{\text{Tropine.}}{C_8H_{15}NO} + \underset{\text{Tropic acid.}}{C_9H_{10}O_3}.$$

On warming tropine (tropanol) and tropic acid with dilute hydro-loric acid we only obtain atropine, as any hyoscyamine formed is imme-tely changed into atropine.

As tropine combines with tropic acid so it also combines with other yacids, producing compounds called *tropeines*. With mandelic acid . 498) and tropine we obtain *homatropine*, $C_{16}H_{21}NO_3$, which is used in edicine instead of atropine.

denylic acid, and yields on further
(p. 542).

b. Paranucleoproteids.

yield proteid and acids of unknown composition
nucleic acids ($C_{18}H_{25}N_3P_2O_{12}$, etc.). On boiling the
alkalies or dilute acids, phosphoric acid, proteid,
ses, are produced.
ounds of paranucleic acid with proteid, also con-
med from the paranucleoalbumins in their peptic

s, compounds of paranucleins with proteids. They
ent of protoplasm and also occur in secretions, etc.
ls and are insoluble in water but dissolve in the
caustic alkalies. Their neutral solutions do not
are incompletely precipitated by NaCl and com-
n standing with alkalies or acids in the cold the
compose in an analogous manner to nucleoalbu-
this group belong the mucin of ox bile, *ichthulin*
icoproteid in Helix pomata. These latter split into
(p. 566, *d*).

t paranucleoalbumins are the *caseins*. They are
r solutions by heating to 130°–150° and also at
by certain ferments as well as by the careful addi-
ein precipitated by rennin is different from that
pitated by acids. Cheese is a putrefactive product
ilk of all mammals can be precipitated by rennin,
th $MgSO_4$. If a few drops of acid or some rennin
casein separates out immediately and at the same
with it (curdled milk). In the solution we have
l the salts. This solution is called sweet whey. If
l for a long time it also coagulates, due to the for-
om the milk-sugar. The filtrate from this curd

as *ovovitellin* in the yolk of the egg, as α and β
lline lens, also as *phytovitellins* (phytoglobulins) in
utin, *legumin*, *vicilin*, *artolin*, etc. *Thyreoglobulin*,
ne thyroid gland, splits with acids into *thyroiodine*
es not belong to the proteids.
re compounds of lecithins (p. 434) with vitellins
umins and are found in the mucous membrane
he kidneys, etc.

c. Chromoproteids.

omposed into proteid and a ferruginous pigment
in the presence of oxygen is oxidized to hæmatin
ble in water and salt solutions and on heating
, even below the boiling-point, a brown precipi-
l and hæmatin. Alcohol, alkalies, or acids (even
ge even in the cold.

d. Monosaccharide-splitting Enzymes.

Zymase, alcoholase, contained in the fluid pressed from previously destroyed yeast-cells, produces alcoholic fermentation (p. 354). Similar enzymes to zymase have also been found in animal cells.

e. Glucoside-splitting Enzymes.

Emulsin, synaptase, of the sweet and bitter almond, splits the glucosides amygdalin and salicin.

Myrosin, of the white and black mustard-seed, splits the glucoside potassium myronate (p. 438).

f. Glyceride-splitting Enzymes.

Lipase, steapsin, steaptase, occurs in the pancreas of all carnivora as well as in certain plants.

g. Coagulating Enzymes.

Rennin, chymosin, coagulates neutral casein solutions, occurs in the gastric juice of the calf and sheep. A similar enzyme is also found in various varieties of Fiscus and other plants.

Fibrin ferment, thrombin, thrombase, converts fibrinogen into fibrin (p. 567) in the presence of neutral salts.

Gluten ferment (?) converts the proteids of flour into gluten (p. 567).

Pictase, which converts the expressed juice of many fruits into a jelly.

h. Oxidizing Enzymes or Oxidases.

These seem to be a mixture of peroxidases which only oxidize in the presence of peroxides and oxygenases, the latter oxidizing only in the presence of oxygen.

Laccase, in the juice of the Japanese lac-tree, and oxidases related to this also occur in many plants.

Tyrosinase, in many fungi, in the dahlia and potato tubers, beets, etc., oxidizes tyrosin but also many other cyclic compounds.

i. Amide-splitting Enzymes

occur in fungi which cause the fermentation of urine (splitting the urea, p. 410).

j. Reducing Enzymes,

also called *reductases*, cause reduction processes and are found especially in the plants.

Catalase is the name of the enzyme which sets molecular oxygen free from peroxides.

6. Toxalbumins.

In various plants and animals we find bodies which in regard to behavior belong on one side to the food-proteids and on the other side to the enzymes, but they are more or less poisonous. In certain cases their poisonous action is due to toxins which cannot be separated from the proteids by the methods used.

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